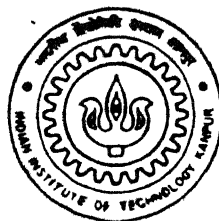# DEVELOPMENT OF AN INTERACTIVE HUB AND SPOKE MODEL FOR BUS TRANSIT NETWORK
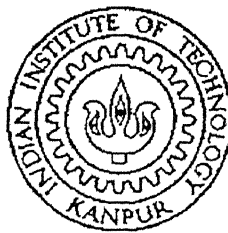
by

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DEPARTMENT OF CIVIL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY KANPUR

July, 1999

DEVELOPMENT OF AN INTERACTIVE HUB AND SPOKE MODEL FOR BUS TRANSIT NETWORK

A *Thesis submitted*
in Partial Fulfillment of the Requirements
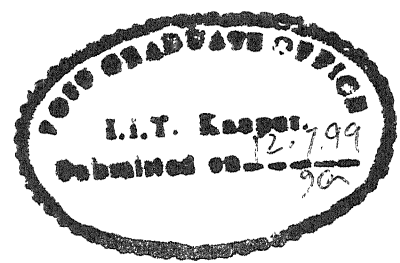for the Degree of
MASTER OF TECHNOLOGY

by
M.RAVI KUMAR

to the
DEPARTMENT OF CIVIL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY KANPUR
JULY, 1999

CERTIFICATE

This is to certify that the work contained in this M.Tech thesis titled **DEVELOPMENT OF AN INTERACTIVE HUB AND SPOKE MODEL FOR BUS TRANSIT SYSTEM** *has been carried out by* M.RAVI KUMAR *under my supervision and has not been submitted elsewhere for any degree or diploma.*

Supervisor
Dr. B.R. Marwah
Professor
Dept. of Civil Engineering.
Indian Institute of Technology
Kanpur

12 July 1999

DEDICATED

TO

MY PARENTS

Acknowledgement

Abstract

The objective of this study is to develop an interactive hub and spoke model for bus transit network. The model identifies the hubs(primary terminals) based on the distance criteria and identifies the stops influenced by each hub. The hubs identified are connected by inter hub routes. These routes are generated by selecting two hubs at a time between which alternative routes are generated. These alternatives are generated by meandering along the shortest path. Each alternative is evaluated by calculating route utilization coefficient, desired passenger time per unit travel time and based on these parameters the best route is selected. The stops in the influence area of a hub are connected to hub by feeder routes. Feeder route is generated by selecting a stop which is farthest from the hub and not connected to hub. Alternatives between the hub and stop are generated by meandering along the shortest path. Alternative having maximum value of demand per route length is selected. Then the model estimates the number of bus trips on each feeder route. The user can see the graphical display of all the hubs, hub with stops and its influence area, feeder routes of a hub and inter hub routes. So that user can understand the system well.

This model is tested with the data of Delhi network. The results indicate that the number of hubs identified decreases with the increase of distance. Number of stops influenced by a hub increases with the increase of influence area. The number of inter hub routes generated increases with the increase of meandering factor or minimum demand between the stops. The number of feeder routes generated depends upon the number of stops in the influence area of a hub and spatial distribution of the stops.

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Chapter 1

Introduction

1.1 Prelude

The phenomenal growth of cities in developing countries like India in the past two or three decades has caused rapid rise in ownership of private automobile and thus necessitated a radical thinking of urban transport policies and programs. The main urban transportation problems are Traffic congestion, air pollution, environmental degradation, higher road accidents, Increased inaccessibility of under privileged, waste of energy.

The supporting and contribution problems are higher population growth, increased vehicle ownership, longer average trip making, ribbon development, inadequate land use control, incompatible traffic mix, distortion of urban form and density configuration, poor traffic management and enforcement, inadequate transport facilities, lack of driver education ,traffic discipline, inadequate cost recovery measure, inefficient operated public transport services(Agarwal,1996).

The above problems provide convincing evidence that drastic action must be taken to provide or improve the urban transit system in order to alleviate these problems.

Among various means of public transportation, the bus transport is bound to dominate because of its door-door accessibility and flexibility in operation . Although demand for bus demand for bus transportation is high, poor planning strategies and inefficient operational methodologies are causes of the heavy losses incurred by many bus operators mainly in public sector.

Among main issues of direct concern such as route

scheduling,crew scheduling, maintainance scheduling , the design of bus routes and bus scheduling may be considered the primary one. optimally designed bus scheduling involves little investment but can radically improve the performance of the system.

The success of mass transportation system depends on the proper route layout , scheduling and operational reliability. This can be achieved by either intuition and experience or mathematical optimization methods.

Most mathematical programming techniques aim at the optimization of single objective but, given the considerable number of variables and constraints , heuristic approach can be utilized to produce a good solution.

1.2 Statement of problem

The bus transit network planning process involves

* The generation of route to satisfy the demand.

* Estimation of the number of trips to be operated for specific time period on each route and the number of buses required to perform those trips.

* Preparation of timetable for specific period.

The above stages of design should be carried by proper planning to get the best results.

The bus transit network involves the identification of terminals for a route, and the route connecting those terminals.The transit network consists of a number of routes so as to satisfy the demand pattern in an optimal manner. If direct connections are provided for each O-D pair, then this will result in large number of routes on the network, which is not economical. The route should be so structured that beside's satisfying the demand pattern, these also ensure that minimum level of load factor along the route. The literature shows that the nature of routes is basically of two types:

* Destination oriented routes.

* Direction oriented routes.

1.Destination oriented routes:

In destination oriented, method the routes are designed to satisfy the demand from one node to other node. The procedure for generating path for destination route involves:

* Identification or selection of terminals.

* Generation of alternative paths between terminals.

* Evaluation of alternative paths based on different criterion.

* Selection of optimal path.

The first alternative path is generally taken as the shortest path. The alternative paths are considered taking meandering along the shortest path, subject to various constraints. Meandering away from shortest path permits more demand to be satisfied but too much excessive meandering increases travel time of passenger and high cost to society. In various (Marwah,1995) studies the meander is considered to be about 1.4 -1.5 times the shortest distance between terminals. The choice of the meandering factor affects the overall operation of transit network. Another important parameter is minimum demand level to be satisfied by the route along its path.

2.Direction oriented routes.

In Direction oriented routes, the buses move along the major corridors in certain directions. These type of routes generally provide a direct and fast movement between major stops. The design of the Rapid Transit system is also based on direction oriented approach.

For the routes along the major corridors, specific problems involved are:

* The peak periods load factor is very high.

* Passengers waiting time increases considerably.

The demand along the major corridors is significantly affected by various factors such as closing and opening time of offices, factories, schools, etc. In the operation of the direction oriented routes the desired headways are estimated for both peak and off peak periods and the system is operated based on predetermined headways.

Hub and Spoke Model

In Transit network planning of intracity, especially new ones, combination of both destination oriented approach and direction oriented approach should be adopted to get optimal transit network. Hub and spoke model Fig1.1 is well suited for the planned ones, especially where distance between major stops is more and there are large number of stops surrounding major stops.

Under Hub and Spoke routing pattern, hub routes include the primary routes. Inter Hub routes interconnecting the primary terminals amongst themselves and secondary routes (feeder routes connecting the hub) interconnecting secondary stops with primary terminals with subject to some constraints. Feeder routes are the routes which meets the unsatisfied demand, the travel demand of unconnected adjoining bus stops is aggregated at the centroid through secondary feeder routes. These feeder routes are called spoke routes..
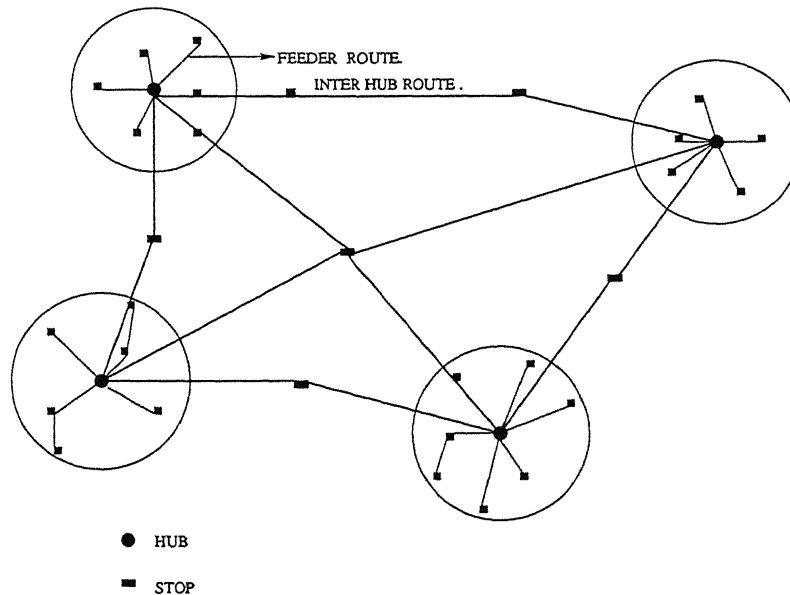
Figure 1.1: Hub and spoke model.

1.3 Objectives and Scope of present study

This study aims to develop a hub and spoke bus transit network model with interactive graphic package. The overview of model involves:

1. Identification of Primary terminals (hubs).

2. Identification of stops coming under the influence area of a hub.

3. Generation of routes connecting hubs (inter hub routes).

4. Generation of feeder routes connecting stops with hub.

5. Graphical display.

* Display of hubs with details.

* Display of feeder routes (routes connecting spokes and hubs).

* Display of inter hub routes.

The study also aims to test the sensitivity of some parameters . The various sensitivity parameters are:

* The distance criteria (The minimum distance between two hubs) in the identification of hubs.

* The influence distance in the identification of stops influenced by a hub.

The above objectives of the study are primarily application oriented and it is proposed to test the developed models for the network of Delhi Metropolitan area.

1.4   Literature Review

Cherqui(1975) attempted to treat routes as common lines, formulating the problem as an optimization problem with a probabilistic context. Hsu and surti(1975) gave a method of optimal bus network design based on nodal demands. Dhingra (1980) developed a simulation model for the scheduling problems of public bus transportation system based on heuristic approach. It simulates the flow of passengers on all the nodes of a network , there by taking into account of interaction effects of overlapping, crossing, merging and diverging routes. Routes have been designed based on travel demand. Lam and schuler (1982) studied a system wide transit routing and scheduling as an optimization problem.

Marwah and patnaik (1984) developed a method in which selection of routes and frequencies was done simultaneously. Chua(1984) distinguishes some methodologies for bus network namely manual design, Market Analysis project(MAP), system Analysis with Interactive Graphics(SAIG) etc.

Janarthan and Scheider(1986) developed alternate transit design by multi criteria method using concordance analysis in which the alternatives are evaluated by a series of pair wise comparisons.

D . L . Van Oudeusden, S.Ranjithan and K.N. Singh(1987) developed an interactive modelling approach to solve the practical problem of bus route network design. kopelman(1989) dealt the problem of transit routing as an optimization problem. Demand oriented network generation was presented by Moorthy(1989).

K.sekhar (1995) designed interactive bus system using heuristic approach. The study was to develop bus routing and scheduling of intercity transit system. The generated routes were displayed graphically to aid the user to select the route.

Sayeeram(1998) developed a model for dynamic scheduling of buses on a corridor and sensitivity analysis for the generation of primary routes for large network. The parameters selected for sensitivity are meandering factor to be adopted for the generation of routes , the minimum demand level for primary routes.

1.5   Organization of thesis.

In the following chapter 2,model description ,model formulation ,inputs and outputs of model are discussed. chapter 3 consists of features of the programming. chapter 4 consists of analysis of results and sensitivity analysis of some parameters after applying the system of models for Delhi road network. chapter 5, conclusions and scope of future work.

Chapter 2

Model development

2.1 General

Transit planning is one of many objective problems that have conflicting goals. This means better performance of one objective often cannot be achieved without negatively affecting the other. The services of a public Transportation system is represented by routes and schedules. Economy in operation, reliable and adequate level of service to the users should be primary objective of any transport management policies. The efficient way of operating the intracity transit system is to develop optimal route network and scheduling system in addition to the transport integration facilities i.e parking lots etc. This should be done with the minimum amount of resources. The above objectives are met by proper planning methodology of :

* Structuring of routes in order to meet the demand for the travel in an efficient manner.

* Determination of optimum schedules with the minimum resources.

2.2 Heuristic Approach for Generating Bus Transit network

Any intuitive approach to the transit network planning problem cannot provide reliable answers. Mathematical Programming approach is theoretically rigorous but fails to handle problem of large networks due to the intricate nature

of the factors involved. Heuristic algorithms based on experience suits for these type of problems.

2.3 Overview of the model

The overall model Fig2.1 development is divided into number of sub models. The model consists of following sub models.

1. Identification of primary terminals(hubs).

2. Identification of stops coming in the influence area of a hub.

3. Generation of inter hub routes.

4. Generation of feeder routes connecting hub.

5. Scheduling of bus trips on feeder routes.

2.4 Identification of primary terminals(hubs)

For efficient transit system, it is important to find out the primary terminals (hubs) which are the major traffic generators. The distance between the hubs should not be very less. If distance is less, large number of hubs are generated . This increases the accessibility of stops. But at the same time if distance is more then large number of Inter hub routes are generated which may not be economically feasible. If on the other hand distance is very large, it decreases the accessibility. Therefore the distance criteria should be decided taking into account accessibility and cost.

Production at each stop is the summation of the demand between the stop and all other stops in the network. Mathematically it can be represented as

$$Pi = \sum_{j=1}^{n} d(i,j) \qquad (2.1)$$

where P_i is the production at stop i, d(i,j) is the demand between the stop i and stop j and n is the number of stops. The production at each stop is used in the identification of primary terminals(hubs).

The methodology Fig2.3 adopted for finding of hubs is:
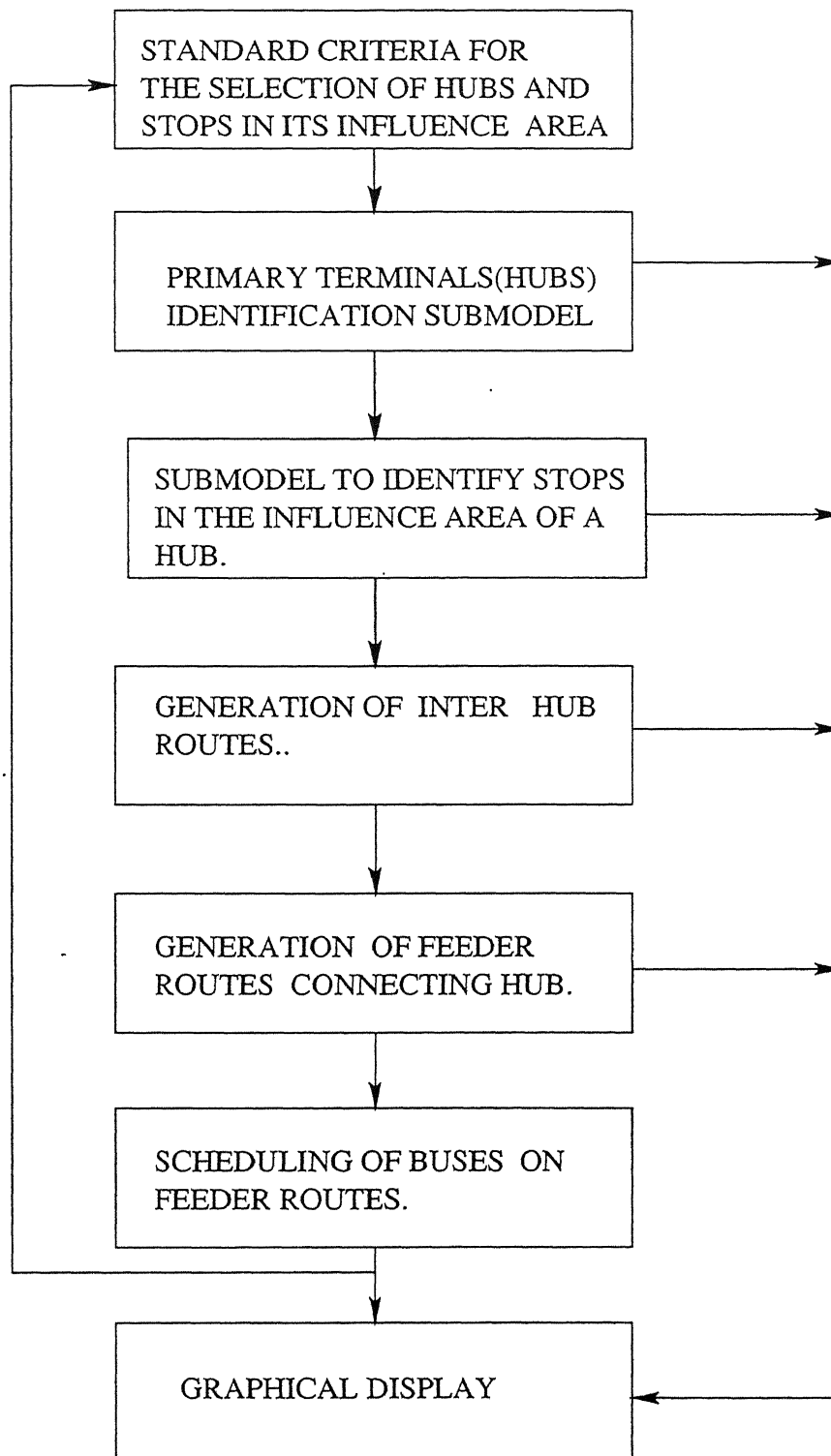
Figure 2.1: Overview of model system.

The process starts with the generation of production data file using Input sub model Fig2.2 and shortest path matrix. The stops in the production file are arranged according to their production in descending order. Initially the stop with highest production value is fixed as a terminal(hub). Then reading each stop from production file , if distance of this stop from each of the previously selected hubs is greater than distance criteria this stop is fixed as a hub. If distance is less than distance criteria with any of the previously selected hubs next stop is read and this process is continued till the end of file.
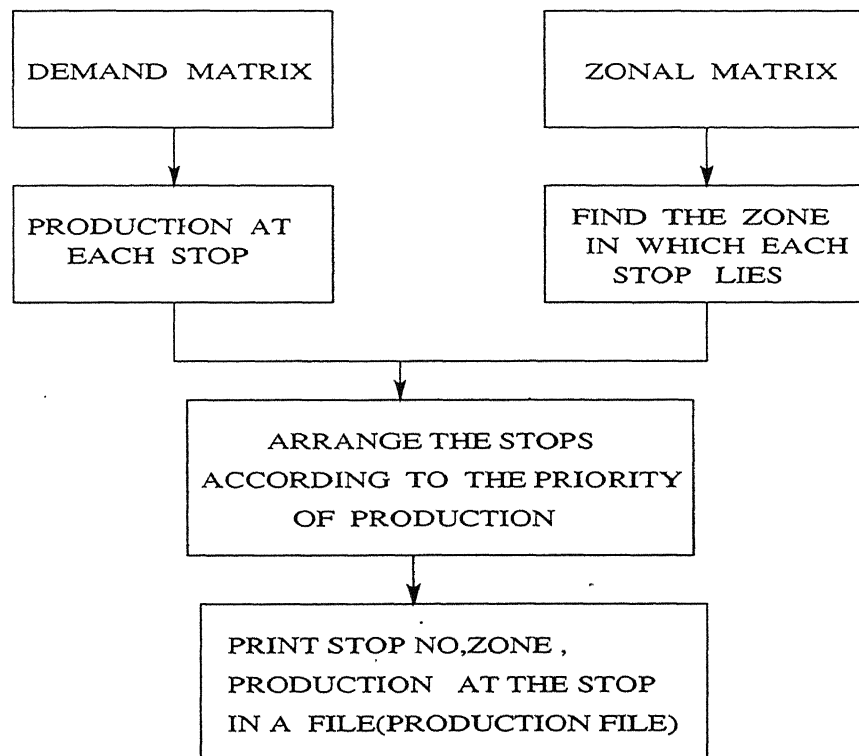
Figure 2.2: Input submodel

2.5 Identification of stops within the influence area of a hub

After the identification of the primary terminals, it is required to identify the stops which are influenced by a hub. The influence area is the
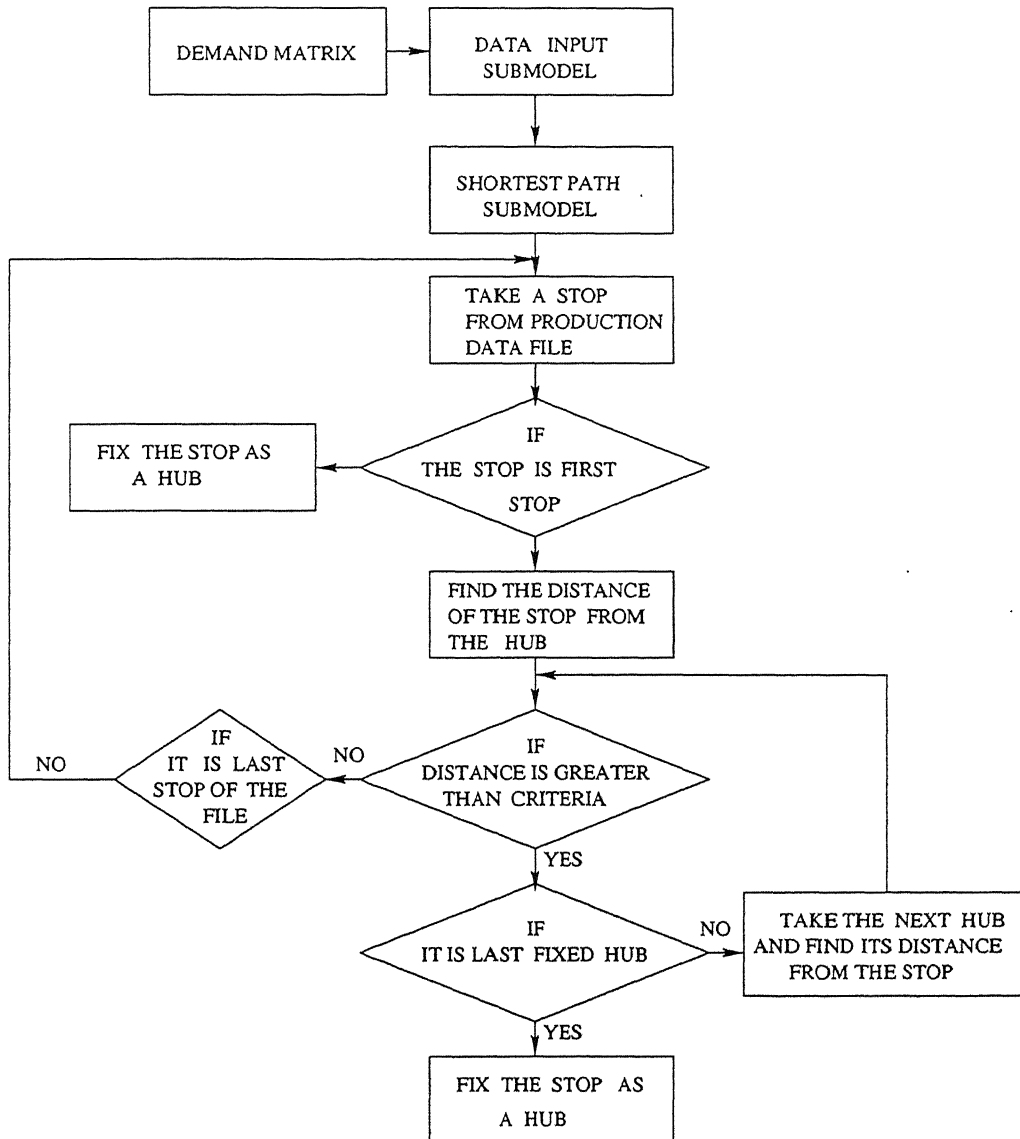
Figure 2.3: Methodology for the primary hubs

distance up to which the stops come to hub to transfer to the stops which are not influenced by the hub.

The influence area depends upon the location of the hub(whether it is located in the interior of the city or exterior of the city). The influence area should not be more than the distance criteria between the hubs.

The methodology adopted for finding out the stops which come in the influence area Fig2.4 involves following steps:

1. Using the production file the zone in which hub lies is found.

2. Using the zonal region file the location of the hub is found and based on its location its influence distance is fixed.

3. Then using the criteria the stops in the influence of a hub are found.

Criteria.

if dis(hub,j)$<$ Infl_area   then the stop comes in the influence of a hub.

$\forall$ j=1to n

where dis(i,j) is the shortest distance between the stop i and j, Inf_dis is the influence area and n is the total number of stops.

2.6   Generation of inter hub routes.

2.6.1   Introduction.

The inter hub routes are the routes on the major corridors providing accessibility between two hubs. These routes satisfy high demand . The frequency of the buses on these routes is very high, speed is also very high. Therefore these terminals should not be very close or very far.

The procedure for generating path of a route involves:

1. Identification or selection of hubs for the route.

2. Generation of alternative paths between the hubs.

3. Evaluation of alternative paths and finally selection of optimal path.
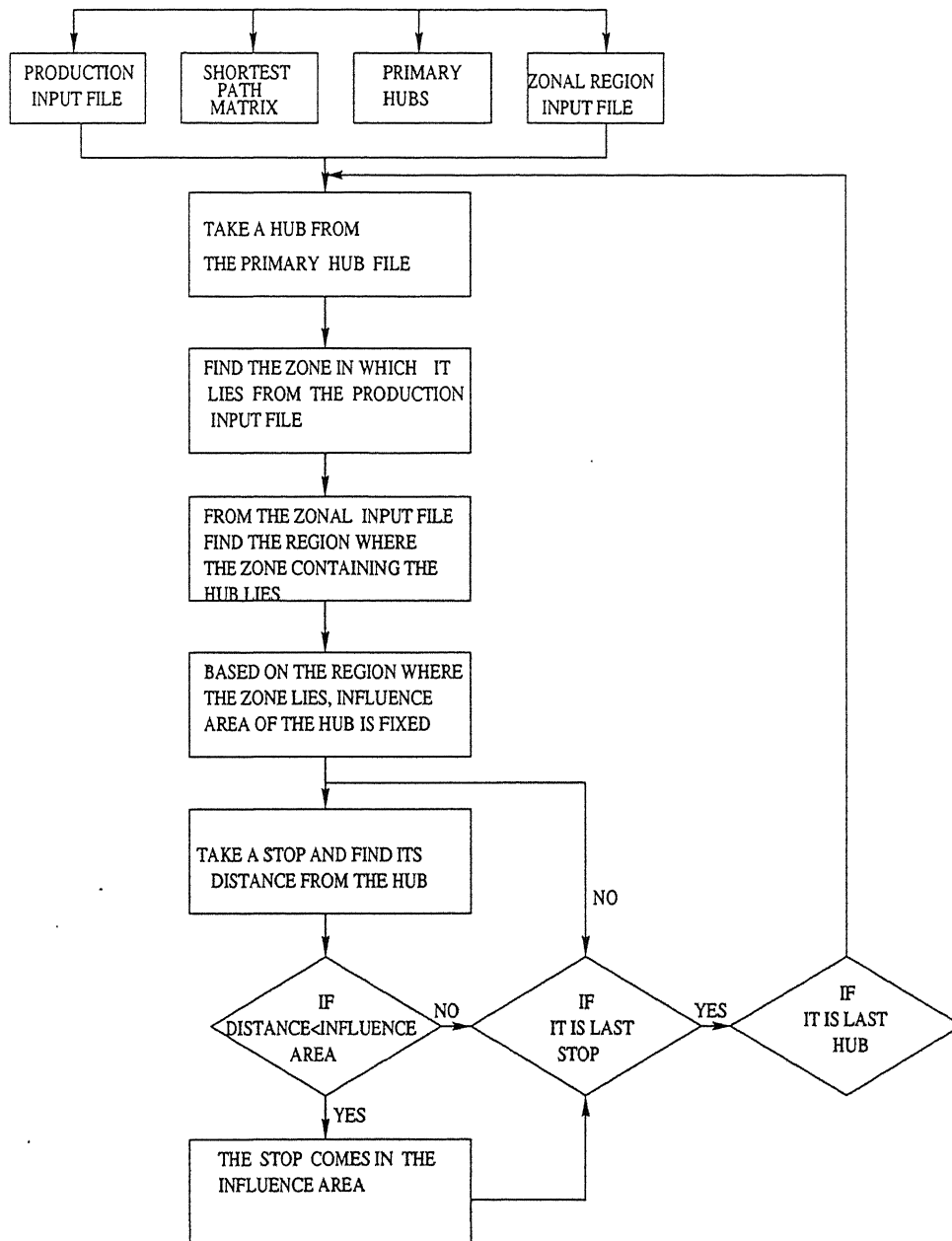
Figure 2.4: Identification of stops coming in the influence of hub.

The first alternative path is generally taken to be shortest path. The alternative paths are considered by meandering along the shortest path subjected to various constraints of travel demand and travel distance. Meandering away from shortest path permits more demand to be satisfied, but excessive meandering increases travel time of passengers and operating cost. In various studies (Dashora 1991) , the maximum meander is considered to be about 1.4-1.5 times the shortest distance between the terminals. The choice of this meandering factor will effect the overall planning and operation of transit network.

2.6.2 Modification of inter stop demand.

In hub and spoke model, the demand from a stop inside a hub to a stop outside the hub transfers at the hub. Therefore inter stop demand changes.

The total production at a hub increases but there will only be little variation of the production at the other stops.

There are stops which are not influenced by any hub, during the modification of demand process these stops are temporarily considered as hubs. Initially the modified demand matrix is initialized to zero.

$dm(i,j) = 0$, $\forall$ i , $\forall$ j, where dm is the modified demand matrix.

Some of the stops are influenced by more than one hub, therefore the demand between any stops is divided and then adjusted to different hubs.

If stop i comes in m hubs and j comes in n hubs.

$dmsh(i,j) = d(i,j)$ / $(m \times n)$, where $dmsh(i,j)$ is share of demand of total demand between stop i and stop j.

There are five types of trips in hub and spoke model, based on the type of trip between the two stops, demand is adjusted. they are:

Trips between stops which are under the influence of the same hub(Fig 2.5a).

$dm(i,h1) = dm(i,h1) + d(i,j)$.
$dm(h1,i)=dm(i,h1)$.
$dm(h1,j)=dm(h1,j)+d(i,j)$.
$dm(j,h1)=dm(h1,j)$.

Trips between stops which are under the influence of different hub-s(Fig 2.5b).

dm(i,h1) = dm(i,h1) + dmsh(i,j).
dm(h1,i) = dm(i,h1).
dm(h1,h2) = dm(h1,h2) + dmsh(i,j).
dm(h1,h2) = dm(h2,h1).
dm(h2,j) = dm(h2,j) + dmsh(i,j).
dm(j,h2) = dm(h2,j).

Trips between a hub and stops which are in influence of other hub(Fig 2.5c).

dm(h1,h2) = dm(h1,h2) + dmsh(i,j).
dm(h2,h1) = dm(h2,h1).
dm(h2,j) = dm(h2,j) + dmsh(i,j).
dm(j,h2) = dm(h2,j).

Trips between a stop and hub which is not influencing the stop(Fig 2.5d).

dm(i,h1) = dm(i,h1) + dmsh(i,j).
dm(h1,i) = dm(i,h1).
dm(h1,h2) = dm(h1,h2) + dmsh(i,j).
dm(h2,h1) = dm(h2,h1).

Trips between two hubs(Fig 2.5e).

dm(h1,h2) = dm(h2,h1) + dmsh(i,j).
dm(h2,h1) = dm(h1,h2)

2.6.3   Description of routing model.

2.6.3.1   Introduction.

A summary of the routing model adopted for the generation of inter hub route is presented in the following subsections. This model has not been developed as part of this study but has been adopted from other studies(RITES,1998). The various submodels are shown in Fig2.6.
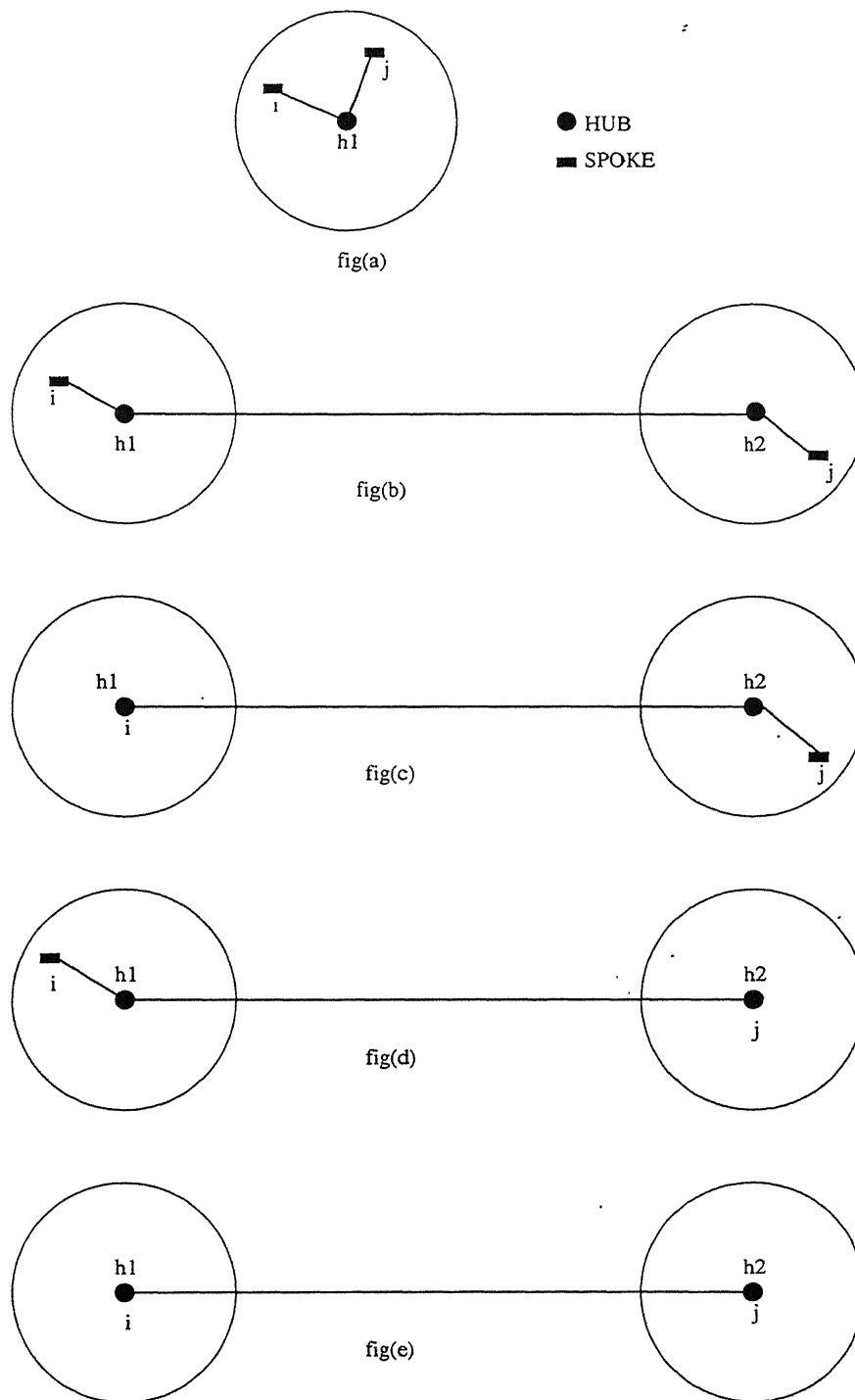
Figure 2.5: Different pattern of trips between hub and spoke

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│      ROAD NETWORK       │        │     DEMAND MATRIX       │
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SELECTION OF TERMINALS FOR PATH
FROM PRIMARY HUBS

GENERATION OF SHORTEST PATH

GENERATION OF ALTERNATIVE PATHS

ANALYSIS OF ALTERNATIVES TO FIND
BEST

ADJUSTMENT OF DEMAND MATRIX
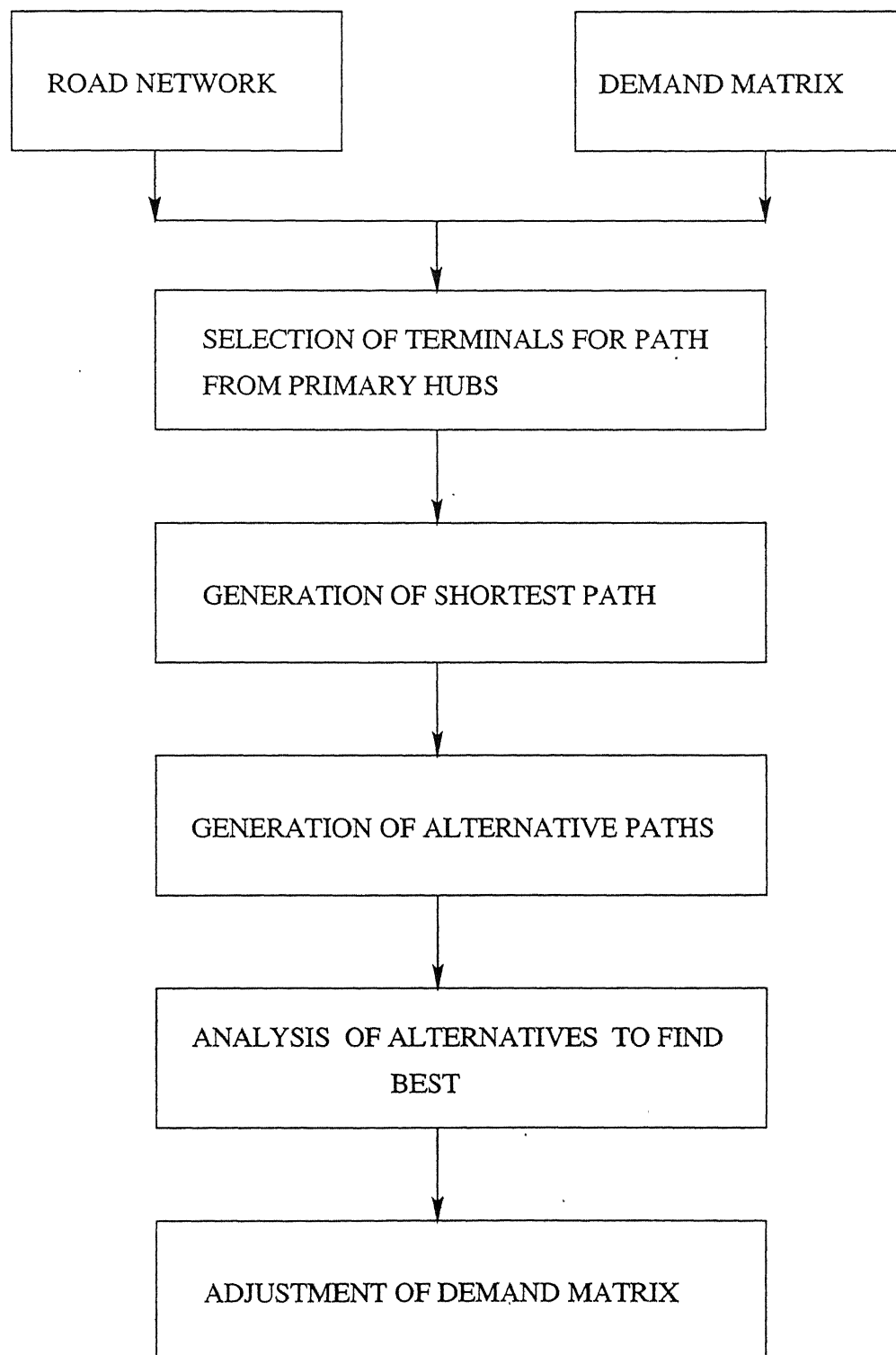
Figure 2.6: Methodology for inter hub route generation.

2.6.3.2   Data Input submodel.

The data required for this model are:

* The road network of the study area.

* Inter stop travel demand matrix.

* Already identified hubs.

* Link distance file.

2.6.3.3   Selection of terminals.

Generally nodes with significant traffic demand are treated as major traffic generators, and are selected as terminals in the bus transit system. The methodology for the identification of primary terminals is discussed in section(2.4). Then two terminals are selected at a time from already identified terminals to generate route between them. These are selected based upon some constraints. The various constraints are :

* Minimum demand between the hubs(cut off demand).

* Minimum distance and maximum distance between the hubs.

2.6.3.4   Shortest path generation.

The shortest path between the selected pair of terminals is generated as first alternative. The program uses the Dijkstra's shortest path algorithm to find the shortest path between identified terminals. Also the total demand satisfied by this path, and demand satisfied per unit length of the route are determined.

2.6.3.5   Generation of alternative Routes.

Beside the shortest path , a number of alternative paths are also generated by meandering away from the shortest path. The number of alternative paths depends upon the meandering factor and the minimum demand satisfied along the path. Any alternative path greater than the shortest path may provide more accessibility to the close by unconnected nodes. The choice of the terminals for a route also depends upon the direct passenger demand between the terminals.

An alternative path is considered to be feasible if it provides higher level of satisfication. The demand satisfied per unit length for each generated alternative is estimated. If demand satisfied per unit length for an alternative is higher than that along the shortest path, the alternative is considered to be feasible for the analysis.

2.6.3.6 Evaluation of alternative paths.

The various alternatives generated are evaluated based on the criterion described below. The steps involved in this procedure are

1. Analysis of a path to estimate various statistics.

2. Criteria for selection of route path.

Analysis of route

The following statistics are determined for each of the alternative route

DEMAND SATISFIED: The number of passengers who are satisfied by the route.

PASSENGER PER KILOMETER: It is equal to the ratio of demand satisfied and route length.

AVERAGE LINK DENSITY: Link density is calculated as

$$(Link\,density)i = (Flow\,on\,link)i/(Length\,of\,link)i \qquad (2.2)$$

$$Average\,link\,density = (\sum_i(Link\,density)_i)/N \qquad (2.3)$$

where N is the total number of links along the path.

LINK UTILIZATION : It is the utilization of link with respect to maximum linkflow.

$$(Link\,utilization)_i = (Flow\,on\,link)_i/(Maximum\,flow) \qquad (2.4)$$

ROUTE UTILIZATION COEFFICIENT(R.U.C): The route utilization coefficient is calculated as,

$$R.U.C = \frac{\sum_n f_i l_i}{f_{max} \times \sum_n l_i} \qquad (2.5)$$

where f_i = Flow on link i.

l_i = length of link i.

f_{max} = Maximum link flow.

n = Total number of links along the path.

Criteria of Selection

The various criteria which may be used for selection of the routes are:

Passenger_km criterion : The route with maximum passenger kilometer can be selected.

Drawback: If demand satisfied along two different alternatives is same, then by this criteria longer path will be selected giving setback to operator's objective.

Average link density criterion : The choice may be one which maximizes the average link density. so if the demands of two routes are same then by this criteria shorter route will be selected.

Drawback: Every link in this criteria is given equal weightage whereas longer links should get higher weightage.

Route utilization criteria : The route with maximum value of route utilization coefficient is better than the above criteria.

Criteria adopted in this model

Let there be n stops (1,2.3......,n) along the alternative path.
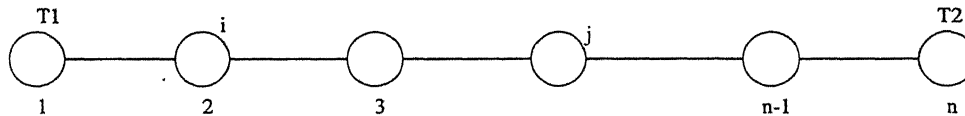
let i,j be some intermediate stops, there are (n-1) links on this alternative path and let l th link, and $(t\_time)_l$ be the travel time for l th link. Instead of considering distance, travel time is more appropriate because of variations in speed along different links.

The statistics estimated are:

a) Route length --The total length of the path in meters.

b) Route travel time - The total travel time over all the links of the path.

c) Demand satisfied along the path

$$Demand\,satisfied = \sum_i \sum_j Dem_{ij} \qquad (2.6)$$

d) Average link flow:

$$(Link\,flow)_l = \sum_{i=1}^{l} \sum_{j=l+1}^{n} Dem_{i,j} \qquad (2.7)$$

e)Route utilization coefficient: The route utilization coefficient is calculated as,

$$R.U.C = \frac{\sum_n f_i l_i}{f_{max} \times \sum_n l_i} \qquad (2.8)$$

where f_i = Flow on link i.

l_i = length of link i.

f_{max} = Maximum link flow.

n = Total number of links along the path.

f) Total passenger time for the alternative path

$$\sum_i \sum_j Dem_{i,j} \times (t\_time)_{i,j} \qquad (2.9)$$

where $(t\_time)_{i,j}$ = Actual travel time along the path from node i to node j.

Passenger_time / unit travel time

$$\sum_i \sum_j Dem_{i,j} \times (t\_time)_{i,j} / Total\,Travel\,time \qquad (2.10)$$

g) Desired passenger_time

$$\sum_i \sum_j Dem_{i,j} \times (s\_time)_{i,j} \qquad (2.11)$$

where $(s\_time)_{i,j}$ is shortest travel time between node i and j, this is the time which the user desired to have.

Desired passenger _time / unit travel time

$$\sum_i \sum_j Dem_{i,j} \times (s\_time)_{i,j} / Total\,Travel\,time \qquad (2.12)$$

The adopted model makes selection of the optimal path amongst the alternative as follows:

1. Shortlisting of alternatives for final selection: Those alternative paths for which the R.U.C is greater than that of (R.U.C of shortest path - 0.1) are shortlisted, and considered for further selection. In this way the alternatives with low value are ignored.

2. Selection of optimal path: The optimal alternative is one which has the maximum value of desired passenger time per unit travel time. Only short listed alternatives are considered.

The above criteria thus not only maximizes the desired passenger time per unit time but also ensures a higher value of R.U.C.

Finally the route is selected only if the demand served by the route is more than the feasible demand.

2.7   Model for generating feeder routes.

The routing model Fig2.7 consists of following steps.

1. Initialize the Input data.

2. Modifying the inter stop demand matrix.

3. Identification of alternative routes.

4. Analysis of alternative routes to find the best route.

5. Adjusting of modified demand matrix.

6. Checking for termination criteria.

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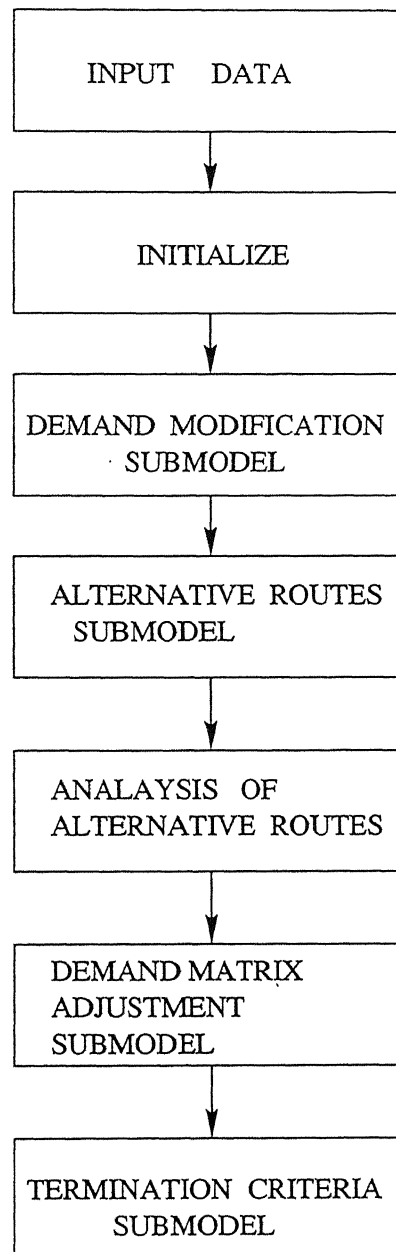
Figure 2.7: Routing sub model

2.7.1 Initializing the Input data.

The Input data consists:

1. Inter stop demand matrix.

2. Link connectivity data file.

3. File containing hubs with the stops coming in the the influence area of the hub.

4. Shortest distance data file.

From the Input data, the required data is Initialized. Initially a hub with the stops coming in its influence area are taken. Using the shortest distance data file, the distance of each stop from the hub is found and then these stops are arranged in the descending order of their distance. Each stop as a variable state, it is initially zero.

State as a value = 0   if the stop does not lie on any route.

1   if the stop lies on any route.

2.7.2 Modifying the inter stop demand matrix.

The inter stop demand matrix is modified, because the demand between any stop which is in the influence area of a hub and a stop which is outside the influence distance passes through the hub.

This is shown using Fig2.8.

After the modification the demand matrix $dm_{1,2}$ and $dm_{2,1}$ will remain same and $dm_{1,5}$ and dm_{25} will become zero.

$$dm_{1,0} = d_{1,0} + d_{1,5} \qquad (2.13)$$

where $d_{i,j}$ is the demand between stops i and j, $dm_{i,j}$ is modified demand between i and j.

$$dm_{h,sti} = \sum_{i=1}^{nst} d_{sti,i} - \sum_{j=1}^{n} d_{sti,j} + d_{sti,n} \qquad (2.14)$$

Figure 2.8: Figure representing hub with stops.

where sti is a stop inside the influence distance of a hub, nst is total number of stops in the city network and n is the total number of stops in the influence area of a hub.

Methodology for modifying the demand matrix is shown in Fig2.9.

2.7.3 Generation of alternative paths

For the identified stops in the influence area of a hub a number of alternative bus routes are generated as follows:

Generation of shortest path

The farthest stop(Initial stop from the hub whose state is zero is taken and the shortest path is generated using Dijkstra's algorithm.

Dijkstra's algorithm

The first step in this method is to ensure that there is a distance associated with every pair of nodes in the network. This distance will be the link length if there is a link between the nodes(and shortest link length if there are several links between a pair of nodes). Initially the shortest length between
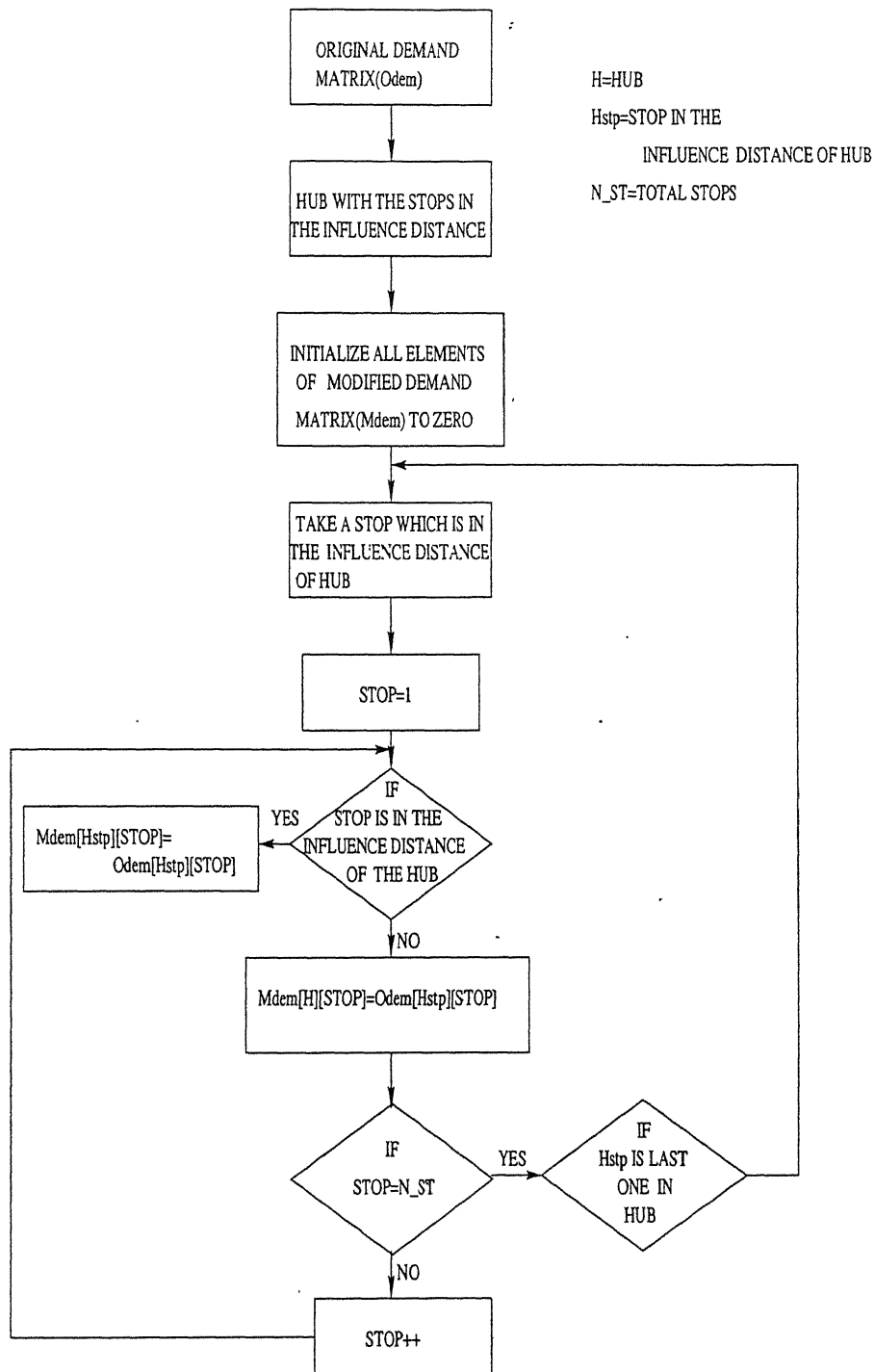
Figure 2.9: Modifying demand matrix

starting node(node from which shortest length should be found)to itself is zero and between starting node to all others is infinity.

Dijkstra's method assigns a label to every node in the network . This label is the distance to that node from the start along the shortest path found thus far. The label can be be in one of the two states : it may be temporary, corresponding to some uncertainty as to whether the path found is shortest of all. The method changes temporary labels into permanent ones the terminal is reached. Formally the Dijkstra's algorithm is as follows:

Step 0: Assign a temporary label(i)=infinity to all other nodes i$\neq$s; Set l(s) = 0 and set p = s. Make l(s) permanent. (p is last node to be made permanent label and is the starting node).

Step 1: For each node i with the temporary label redefine l(i) to be the smaller of l(i) and l(p)+d(p,i). Find the node i with the smallest temporary label, set p equal to this i, and make the label l(p) permanent.

Step 2: If node t has a temporary label, then repeat step 1. otherwise, t has permanent label, and corresponds to the length of the shortest path from the s to t through the network. Stop to find out the route of this shortest length.

Step 3: For each permanently labeled node j other than s of the network define r(j) = i where l(j) = l(i)+d(i,j) and i $\neq$j stop. From the above procedure all the shortest paths between each pair of terminals are found out.

Generation of alternative routes

After the generation of shortest path a number of alternative paths are generated and evaluated to select the final route. Any alternative path will have length greater than the shortest path and may also provide more accessibility to other unconnected stops. The following procedure is adopted in generating the alternate paths.

* The alternative path is found between the initial stop and hub, by passing through every other stop in the influence distance whose distance is zero. each stop whose state is zero gives an alternative.

* Various alternatives paths are retained only if length of these paths is less than 1.5 times the shortest path between Initial stop and hub.

2.7.4 Analysis of alternative paths to find the best route.

The selection of the route from the available alternatives is done by carrying out the analysis of alternative routes.

The following parameters are determined for the shortest path and each of the alternative route.

$$flow\,on\,path(r) \ = \ \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} demand(i,j) \tag{2.15}$$

$$length\,of\,path(r) \ = \ \sum_{i=1}^{n-1} length(i,i+1) \tag{2.16}$$

where n is the last stop on the path r.

$$link\,density(l) \ = \ flow\,on\,path(r)\,/\,length\,of\,path(r) \tag{2.17}$$

SELECTION CRITERIA

After calculating the link density of all the alternative routes. The alternative with maximum link density is selected.

2.7.5 Adjustment of modified demand matrix

After the selection of the best route the modified best route the modified demand matrix should be adjusted because some or all the demand on the links of the route is satisfied.

Adjustment of the demand is done by calculating some parameters, they are

$$link\,flow\,on\,last\,link(lf\_ln) \ = \ \sum_{i=1}^{n} demand(i,n) \tag{2.18}$$

$$Total\,link\,flow\,on\,the\,lastlink(Tlf\_ln) \ = \ (lf\_ln \times n\_ph)\,/\,hw \tag{2.19}$$

where n is the last stop on the route, n_ph is the number of peak hours per day and hw is the minimum headway between the buses.

$$Total\,flow\,on\,the\,route(Tfr) = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} demand(i,j) \qquad (2.20)$$

Adjustment factor(AF)=0   if   Tlf_ln$\geq$Tfr.

            =Tlf_ln/Tfr   if   Tlf_ln$<$Tfr

$$Adjustment\,of\,demand = demand(i,j) \times AF \qquad (2.21)$$

$\forall$ i=1 to n, $\forall$ j=i+1 to n

2.7.6 Termination criteria

After finding the best route the variable state of all stops which are in the route is made one(1). Then the state of all the stops is checked. If state all the stops is 1, then the process is completed.(All the stops influenced by the hub are connected to the hub) else again alternative routes are generated for next initial terminal and process continues till the termination criteria is meet.

2.8 Scheduling Submodel

2.8.1 Introduction

A heuristic algorithm Fig2.10 is adopted for the determination of the optimal allocation of buses on the various feeder routes connecting hubs.

2.8.2 Input data

    * Layout of the various nodes in the transit network.

    * Demand matrix of the transit network.

    * The paths of the generated feeder routes.

    * Link lengths data file.

    * Stops under the influence of hub.

```
┌─────────────────────┐        ┌─────────────────────────┐
│  FEEDER ROUTES.     │        │ STOPS IN INFLUENCE OF A │
│                     │        │ HUB                     │
└─────────────────────┘        └─────────────────────────┘
            │                              │
            └──────────────┬───────────────┘
                           ▼
              ┌───────────────────────────┐
              │  MODIFY THE DEMAND        │
              │  MATRIX                   │
              └───────────────────────────┘
                           │
                           ▼
              ┌───────────────────────────┐
              │ INITIALIZE MINIMUM TRIPS, │
              │ ADDITIONAL TRIPS ON ROUTE │
              └───────────────────────────┘
                           │
                           ▼
              ┌───────────────────────────┐
              │ FOR EACH LINK(I,J)  ESTIMATE│
              │    -LINK LOAD             │
              │    -ROUTES PASSING ON THE │
              │     LINK(I,J)             │
              └───────────────────────────┘
                           │
                           ▼
              ┌───────────────────────────┐
              │ FOR EACH ROUTE ESTIMATE   │
              │ -DEMAND SERVED(R).        │
              │ -MAXIMUM NO. OF BUS TRIPS.│
              └───────────────────────────┘
                           │
                           ▼
              ┌───────────────────────────┐
              │ ESTIMATE NO OF TRIPS ON ROUTE│
              │ BASED ON LINKS LYING ONLY ON │
              │ ONE ROUTE                 │
              └───────────────────────────┘
                           │
                           ▼
              ┌───────────────────────────┐
              │ ESTIMATE FOR EACH LINK    │
              │    -DESIRED BUS TRIPS     │
              └───────────────────────────┘
                           │
                           ▼
              ┌───────────────────────────┐
              │ FOR ALL LINKS WHICH LIES  │
              │ ON MORE THAN ONE ROUTE    │
              │ ESTIMATE                  │
              │   -TOTAL ASSIGNED TRIPS   │
              │   -ADDITIONAL BUS TRIPS   │
              └───────────────────────────┘
                           │
                           ▼
              ┌───────────────────────────┐
              │ FOR ALL ROUTES            │
              │ - ESTIMATE ADDITIONAL     │
              │   BUS TRIPS               │
              └───────────────────────────┘
                           │
                           ▼
              ┌───────────────────────────┐
              │ TERMINATION CRITERIA      │
              └───────────────────────────┘
```

Figure 2.10: Scheduling sub model

2.8.3 Estimation of operating flow characteristics

Let a route have n nodes in the path 1............n. This path will have n-1 links. Let Trips(i,j) be the demand from node i to node j in the path.

The demand is same in both the directions, therefore the number of bus trips are also same in both the directions and the demand is always maximum in the last link of the route , because all the demand from any spoke which goes out of the influence area of the hub passes through the hub.

The demand in the direction of hub.

$$Demand\,served(r) \; = \; \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} Trips(i,j) \qquad (2.22)$$

$$Maximum\,no\,of\,bus\,trips\,on\,a\,route \; = \; \frac{Demand\,served}{Maximum\,average\,bus\,Load} \qquad (2.23)$$

where Demand served (r) is the demand satisfied by the route in the direction of the hub.

The passenger flow on the links of a route influences the number of bus trips on a route.

$$Load\,on\,link(a,b) \; = \; \sum_{r=1}^{n} \sum_{i=s}^{i=a} \sum_{j=b}^{j=h} Trips(r,i,j) \qquad (2.24)$$

where Load on link (a,b) is the passenger flow over the link a and b which may lie on one or more routes, s is the starting node from where route starts and h is the last node of the route.

2.8.4 Level of service

The level of service is measured in terms of the average bus load provided by the bus system . Assign the average bus load for a route at the desired level of service. These average bus loads for various levels of service help to determine the number of bus trips. Table2.1 gives the average bus loads for different level of services.

Table 2.1: Level of service-Average bus load.

LEVEL OF SERVICE	AVERAGE BUS LOAD
LOS-1	40
LOS-2	50
LOS-3	60

2.8.5 Estimation of bus Trips

The number of bus trips to be operated on any route depends upon the demand to be satisfied on that route and the passenger flow on various links of a route. The demand served along a route can give an idea about the desired bus trips to be operated on the route, as some inter nodal demand may be shared by more than one route.

The passenger flows on a link of the network helps to determine the bus trips needed on that link. But as a link may have a number of routes passing over it, the desired bus trips on a link is the combination of the bus trips for all the routes passing over the link. To estimate the optimal bus trips for a route in one direction the following heuristic algorithm is adopted. The algorithm is given below.

1. Generate modified demand matrix using inter stop demand matrix and stops in the influence area.

2. Assign minimum number of bus trips and additional bus trips on each route. Estimate the total passenger flow on all the links, demand served by all the routes and maximum no of bus trips on each route(Eqn:2.23).

3. Taking the link load(Eqn:2.24) and the average bus load at the desired level of service(Table:2.1), the desired bus trips that have to be operated over the link(i,j) are obtained as given below .

$$Desired\,Bus\,Trips(i,j) \; = \; \frac{Link\,load(i,j)}{Average\,Bus\,Load(LOS)} \qquad (2.25)$$

4. Identify Links lying only on one route ,if the number of trips on these link are more than already assigned trips on the route. The trips on the link are assigned to trips on the route.

5. Identify links lying on more than one route and calculate the following parameters. The total bus trips that are required for this link based on the earlier assigned trips for different routes which pass through this link are determined.

$$Assigned\,Bus\,Trips(i,j) \;=\; \sum_r Assigned\,Bus\,Trips(r) \qquad (2.26)$$

for all routes passing over the link(i,j).

6. Then the additional bus trips that need to be allocated to all other routes passing over the link(i,j) are found

$$Additional\,Bus\,Trips(i,j) \;=\; Desired\,Bus\,Trips(i,j) - Assigned\,Bus\,Trips(i,j)$$
$$(2.27)$$

The above obtained additional bus trips may be positive or negative based on the values of desired bus trips and assigned bus trips for that link. Having got the additional bus trips that are to be operated for the link the additional bus trips for the route passing on the link are determined based on the additional bus trips for the link and already assigned bus trips to the different routes. The following gives the additional bus trips to be operated for a route r.

$$Additional\,bus\,Trips(r) \;=\; \frac{Additional\,Bus\,Trips(i,j) \;\times\; Assigned\,Bus\,Trips(r)}{Assigned\,Bus\,Trips(i,j)}$$
$$(2.28)$$

These additional bus trips(r) are replaced only if these trips are less than previously assigned additional bus trips. The revised bus trips for all the routes passing that are passing over the link(i,j) are determined as the sum of the previously assigned trips and additional trips for a route as given below.

$$Revised\,Bus\,Trips(r) \;=\; Assigned\,Bus\,Trips(r) + Additional\,Bus\,Trips(r)$$
$$(2.29)$$

Revised bus trips(r)=Assigned bus trips(r)+Additional bus trips(r) The above mentioned process from step3 continues until termination criteria is meet. Now revised bus trips(r) becomes assigned bus trips(r).

Termination criteria.

Then termination criteria for this process is when additional routes on all the routes become less than some value.

Check.

If revised bus trips on a route exceed the maximum number of bus trips on a route. Assign maximum number of bus trips to revised bus trips and if revised bus trips are less than the minimum bus trips then minimum bus trips are assigned to revised bus trips.

2.9 Graphical representation of influence area of a hub

Influence area is a term used to define a hub with stops coming in the influence distance of a hub.

The main problem in graphical representation of the influence area of a hub is its shape, because influence area cannot be represented as a regular polygon or a circle.

The influence area of a hub is a irregular polygon because all the stops are randomly located in space(Fig2.11a). To represent this area, first we should know the boundary points of this irregular polygon.

Input for finding out these boundary points.

* A file containing coordinates of all the stops.

* A file containing hub with stops in the influence area.

The methodology adopted involves the following steps.

1. Finding out the following parameters.

* Stop having minimum value of x-coordinate($Stp_{xmin}, x_{min}, y_{xmin}$).

* Stop having minimum value of y-coordinate($Stp_{ymin}, x_{ymin}, y_{min}$).

* Stop having maximum value of y-coordinate($Stp_{ymax}, x_{ymax}, y_{max}$).

2. Separating the stops having y-coordinate value more than y_{min} from stops having y-coordinate less than y_{min}.

3. Total stops are divided into four(4) sets(Fig2.11b) based on the conditions satisfied as given below:

   (a) x-coordinate $< x_{ymax}$ && y-coordinate $> y_{xmin}$.

   (b) x-coordinate $> x_{ymax}$ && y-coordinate $> y_{xmin}$.

   (c) x-coordinate $< x_{ymin}$ && y-coordinate $< y_{xmin}$.

   (d) x-coordinate $> x_{ymin}$ && y-coordinate $< y_{xmin}$.

4. Then each set is processed to find out corner points in each quadrant. The process for set(a) involves the following steps.

   (a) Absolute values of slopes of all the stops with stp_{xmin} are found.

   (b) Then the stop with maximum slope(Stp_{msl}) is identified and this becomes one of the border point.

   (c) Then all the stops whose y-coordinate is less than y-coordinate of Stp_{msl} along with Stp_{msl} are eliminated.

   (d) Then the process from step(b) is repeated till all the stops in the set are eliminated.

After finding out the corner points in this set the process is adopted for other sets to find corner points. The process involved in step(b) and step(c) are different for each set. In set(b) stop with minimum slope(Stp_{mnsl}) is taken as the corner point and all the stops with x-coordinate less than Stp_{mnsl} are eliminated. In set(c) stop with maximum slope(Stp_{msl}) is taken as the corner point and all the stops with y-coordinate greater than Stp_{msl} are eliminated.In set(d) stop with minimum slope(Stp_{mnsl}) is taken as corner point and stops with x-coordinate less than x-coordinate of Stp_{mnsl} are eliminated.
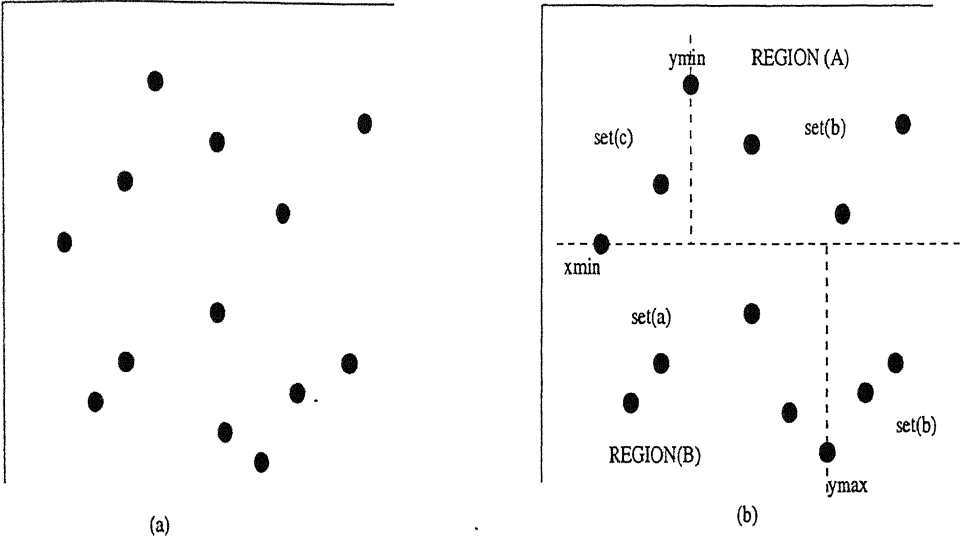
REGION(A)-STOPS HAVING Y-COORDINATE LESSER THAN
Y-COORDINATE OF XMIN STOP..
REGION(B)-STOPS HAVING Y-COORDINATE GREATER THAN
Y-COORDINATE OF XMIN STOP..

Figure 2.11: Random distribution of stops in space.

Chapter 3

Features of programming

3.1 General.

Entire hub and spoke bus transit network model is modeled in 3 modules. Module 1 and 3 are developed for this study and module 2 is adopted from other studies(RITES,1998).Module1 can be divided into 3 submodels, identification of hubs,identification of stops coming in the influence of hub, Generation of feeder routes between hub and stops coming in the influence of a hub. Module2 consists of generation of inter hub routes, methodology of this model is described in section(2.6). Module3 is complete graphical display of hub and spoke model.

The entire model development has been elaborated in chapter(2). The entire model involves lot of evaluation and data processing and deals with large data files. The coding of all the programs of module1 was done in c language in unix environment. All the features of c language were used in the coding of programmes, especially file management. Each model consisted number of sub models. some of the modules of a model were coded separately and linked to the main programme. The coding of module3 was done in c language, in dos environment and some of features of c++ were used, but entire module used c++ graphical header file <graphics.h> for display of this model. The graphical abilities of the programme helps the decision maker to understand the generated transit network well.

3.2 Features.

Following sections elaborate main features of the programmes.

* Generate.

* Display.

3.2.1 Generate.

The main menu displayed after running the program is shown in Fig3.1.

```
                         MENU

    1. Identification of primary hubs.

    2. Identification of stops coming in the influence
       of a hub.

    3. Generation of feeder routes connecting hub.

    4. Scheduling of bus trips feeder routes.

    0. Exit.

    Enter the number of your choice:
```

Figure 3.1: Menu display

3.2.2 Identification of hubs.

This option is used to identify the primary terminals(hubs). This sub model has various sub models.

* Data input.

* Estimation of production at all the stops.

* Identification of hubs.

3.2.2.1 Data Input.

This subroutine prints the names of all the input files with details, so that the user can check whether all the input files are present. At the same time, it asks the user whether he wants to continue or exit. if he continues , it asks for distance criteria required between the hubs.

The input files required are:

1. Inter stop demand matrix(temp5.tmp)

2. Shortest path matrix(sdist5.tmp)

3.2.2.2 Production subroutine.

In this subprogram, the inter stop demand matrix is used to calculate the production at each stop. Then stops are arranged in the descending order based on there production values. The procedure adopted for the calculation of production is given in the section (2.4).

3.2.2.3 Hub identification routine.

In this subroutine based on the distance criteria given, all the possible hubs are identified. The procedure adopted for the identification of hubs is given in section(2.4). The same is adopted here.

3.2.3 Identification of stops influenced by a hub.

This option is used to identify the stops coming in the influence of a hub. This model consists of three sub models, they are:

* Data Input sub model.

* Production sub model.

* Zone and area identification sub model.

* Influence sub model.

3.2.3.1 Data Input

This subroutine prints the names of all the input files with details. Then it asks the user whether all the input files are present or not(1/0). If (1) it asks different influence areas else it exits from the module and comes to menu.

The Input files required are:

1. Inter demand matrix(temp5.tmp).

2. Shortest path matrix(sdist5.tmp).

3. primary hubs(prim_ter.inp).

4. Zonal stop file(area_nod.out).

5. Zonal area file(zon_reg.inp).

3.2.3.2 Production Submodel.

In this subprogram the inter stop demand matrix is used to calculate the production at each stop. Then stops are arranged in the descending order based on there production values. The procedure adopted for the calculation of production is given in the section (2.4).

3.2.3.3 Zone and area identification submodel.

This subroutine finds the zone in which the hub lies using area_nod.out input file and the area in which this zone lies(interior or exterior) using zon_reg.inp input file. Based on the area in which the zone of the hub lies, it picks up its influence area which is already given as input.

3.2.3.4 Influence.

This subroutinue uses the influence area of the hub given as input in previous routine and identifies all the stops which are influenced by the hub. Methodology adopted for identifying these stops is given in section(2.5) and same is adopted here.

3.2.4 Generation of feeder routes.

This option is used to generate feeder routes to connect hub with all the stops which are influencened by the hub. These routes provide accessibility to all these stops. This subroutine as various submodels. They are:

* Data input.

* Demand modification submodel.

* Alternate path generation submodel.

* Route analysis submodel.

* Adjustment submodel.

* Termination submodel.

3.2.4.1 Data input.

This subroutine prints the names of all the input files with details. Then it asks the user whether all the input files are present or not(1/0).

1. Inter stop demand matrix(temp5.tmp).

2. Shortest distance demand matrix(sdist5.tmp).

3. File with hubs and stops which are influenced by these hubs(out2).

4. Link connectivity file(link_arr.inp).

Then it asks the user whether all the input files are present or not(1/0). if (0) it exits else it initializes the status variable state of each stop to zero and selects a stop which should be connected to the hub. The methodology for initializing and selection of a stop is described in section(2.7.1) and same is adopted here.

3.2.4.2 Demand modification.

In this subroutine the inter stop demand matrix is used to get the modified demand matrix(Demand generated at hub and stops influenced by hub). The methodology adopted to get the modified demand matrix is described in section(2.7.2) and same is adopted here.

3.2.4.3 Alternate routes generation.

This subroutine generates alternate routes between hub and the selected stop. First alternative is always the shortest path between the hub and the stop. Other alternative are generated by considering some meandering from the shortest path. The shortest path is found using Dijkstra's algorithm. Dijkstra's algorithm and methodology involved in finding the alternative paths is described in section(2.7.3).

3.2.4.4 Analysis.

This subroutine analyses various alternative routes generated and based on the criteria (maximize *demand/routelength*) it identifies the best route between the hub and the selected stop. The methodology for the analysis of alternative routes to find the best is described in section(2.7.4). The same is adopted here.

3.2.4.5 Adjustment.

This subroutine adjusts the modified demand matrix after the best route is identified, since this route satisfies some amount of demand. The methodology for the adjustment of demand is described in section (2.7.5). The same is adopted here.

3.2.4.6 Termination.

This subroutine checks for termination criteria , if it is meet the program terminates else it selects the next stop using the criteria given in input section. The methodology adopted for termination is described in section(2.7.6).

3.2.5 Scheduling.

This option is used for carrying out the scheduling of bus trips on feeder routes of a hub. The various input data files required for scheduling are:

1. The feeder routes connecting stops with hub.

2. Inter stop demand matrix(temp5.tmp).

3. Stops coming under the influence of a hub.

This model consists of five submodels. They are:

* Moddem.

* Initialize.

* Link demand.

* Iteration.

3.2.5.1 Moddem.

This routine modifies the inter stop demand of stops which come in the influence area of hub. The methodology adopted for modifying the demand is described in section(2.7.2). The same is adopted here.

3.2.5.2 Initialize.

This routine initializes some of the variables before starting the scheduling process. The following variables are initialized:

1. Minimum number of bus trips on a route.

2. Additional number of bus trips on a route are initialized to a large number.

3.2.5.3 Link demand.

This routine calculates the link load(demand on each link), demand on each route, number of bus trips on each link and maximum number of bus trips on each route.

3.2.5.4 Iteration.

This routine finds the number trips on each route. This is a iteration process and starts with minimum number of bus trips and continues still additional number of trips become less than termination criteria.

```
┌─────────────────────────────────────────────────┐
│                                                   │
│        MENU   OF   GRAPHICAL   DISPLAY            │
├───────────────────────────────────────────────────┤
│                                                   │
│     1    Display of  hubs.                        │
│                                                   │
│                                                   │
│     2    Display of feeder routes.                │
│                                                   │
│                                                   │
│     3    Display of inter hub routes.             │
│                                                   │
│                                                   │
│     0     Exit.                                   │
│                                                   │
│                                                   │
│     Enter the number of your choice:              │
│                                                   │
└───────────────────────────────────────────────────┘
```

Figure 3.2: Menu of graphical display

3.2.6 Display.

This program displays the entire hub and spoke system graphically. The main menu displayed after running the program is shown in Fig3.2.

The user can see the graphical display of the selected item and can enter the number of his choice. If you enter any number other than that is in the menu, a warning message is printed and user is asked another number of his choice.

The entire graphical display requires a lot of data the input files required for the graphical display are:

* File containing coordinates of all the stops(node_new.inp).

* File containing names of all the stops.(name_new.inp).

* Link connectivity file(link_arr.inp).

* File containing all the hubs(prim_ter.inp).

* File containing stops influenced by every hub.

* File containing feeder routes of all the hubs.

✳ File containing the corner points of the influence area of all the hubs.

3.2.6.1 Display of hubs.

This option displays all the details of the hubs. The various details of the hub which are displayed are:

1. The entire road network of the city.

2. Location of all the hubs on the network.

3. Name and code of all the hubs.

4. Influence area of all the hubs.

The user is asked to choose the hub of his choice to see the detailed display of hub. The following items are displayed.

✳ Location of hub with its influence area and stops in its influence area.

✳ Names of all the stops in the influence area.

It also gives the information about the total number of stops in the influence area.

3.2.6.2 Display of feeder routes.

This option displays the paths of the feeder routes between the hub and stops in the influence area. The location and names of all the hubs are displayed and user is asked to choose the hub of his choice. After choosing the hub, it displays hub with its influence area and stops. Then Paths of feeder routes between the hub and stops are displayed. The user has the option of seeing this routes in slow motion and lastly paths of all the feeder routes are printed.

3.2.6.3 Display of inter hub routes.

This option displays the path of the route between two hubs. Initially, the names of all hubs are displayed, then the user is asked to choose his initial hub and final hub. If there is no direct route between the hubs it prints the route does not exist" else it displays "The path of the route along with stops through which the route passes.

Chapter 4

Application of the model.

4.1 General.

The model for the hub and spoke bus transit network using heuristic methods has been described in the chapter 2. For the model to be of real use, it should be tested and validated for a real world data. Delhi metropolitan has chosen as the case study problem for testing the developed model.

4.2 Description of the problem.

The study area union territory of Delhi is located at an altitude of 239 meter above sea level in the middle of Great north Indian plains. Delhi is surrounded by Uttarpradesh on the east and Haryana on north south and west.

The study covers an area of 1483sqkm on an average. Delhi is planned on a ring radial pattern with a hierarchical road network. The total road length of Delhi is 22,487 km. Ring road and Outer ring road are the most important arterial roads. The study area is shown in Fig4.1.

The existing transportation network in Delhi and its surrounding areas is predominantly road based. The input for this model is obtained from the data collected from primary surveys, and secondary sources for the study "Optimal Design of Urban Bus system" conducted by Rites for New Delhi metropolitan area(RITES, 1993,1998). The data is available for complete transportation network of New Delhi in terms of link distances, daily bus travel demand pattern for 1542 stops on the network.
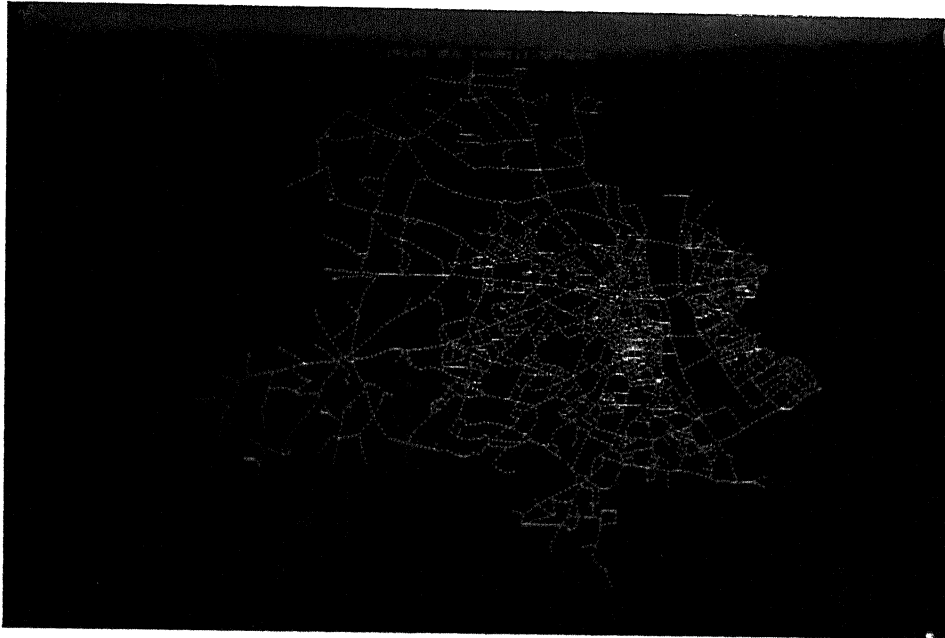
Figure 4.1: Graphical display of the study area.

4.2.1 Data Required.

To investigate any system by modeling, descriptive and quantitative information is a must. In the model described in the chapter(2) the primary hubs, stops coming in the influence area and routes are designed based on the passenger demand and the distance between the stops.

The data required for the entire model consists of:

* Inter stop travel demand matrix.

* The layout of the nodes in the network and the connectivity between each of the nodes, or the links of the network.

* Number of zones in the city with the stops coming in each zone.

The network consists of 1542 stops. The network is shown in Fig4.1.

4.3 Solution.

4.3.1 Identification of hubs.

Hubs are the major traffic generators, these are identified based on the the production at the stops. These should not be very far or very close to each other.The heuristic methodology discussed in section(2.4) is adopted in the identification of hubs. The hubs identified with distance criteria of 7.5 km are given in Tables4.1 , 4.2. A total of 45 hubs (terminals) are identified.

Graphical represention of this hubs is shown in Fig4.2. From the figure it is clear that the terminals are well spread out in the study area.
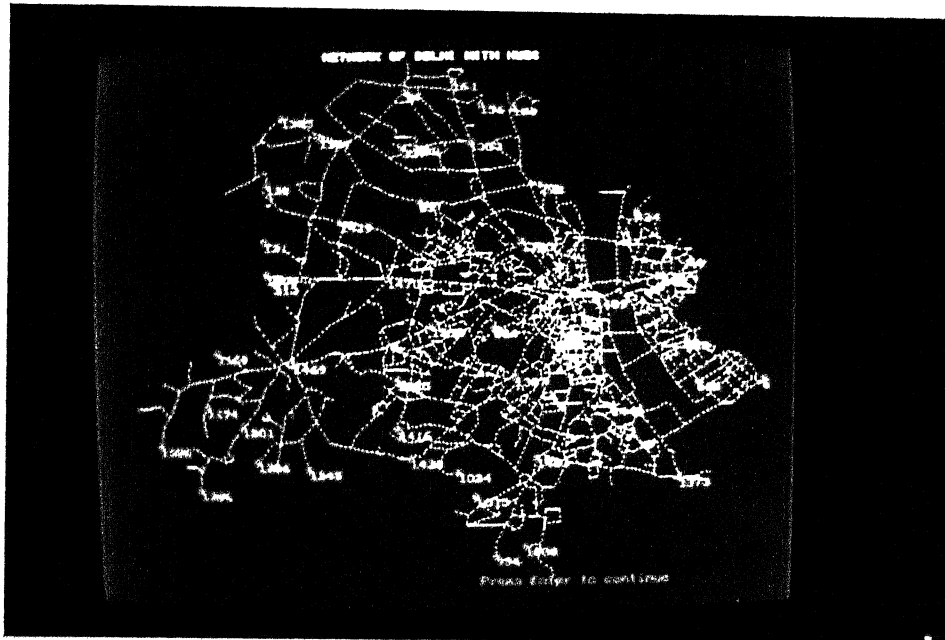
Figure 4.2: Graphical display of hubs.

4.3.2 Identification of stops influenced by a hub.

After the identification of hubs , the stops which are influenced by a hub are found out. The methodology discussed in section(2.5) is adopted in the identification of stops which are influenced by a hub. The results shown in Table4.3 shows the stops influenced by hub Ghanan Hera Mor(1201). The results are obtained by a influence area of 5.0 km for the hub in interior area and 7.5km for

Table 4.1: Hubs identified by distance criteria of 7.5km.

S.no	Code of the stop	Name of the stop
1.	1489	Red Fort
2.	1442	Lajpat Ngr (R Rd) Fruit Market
3.	1350	Azadpur (Sabzi Mandi)
4.	1508	Tilak Ngr
5.	1469	Najaf Garh
6.	1463	Mehrauli
7.	460	Shahadra
8.	1373	Badarpur Border
9.	1367	Bawana N
10.	1387	Dhaula Kuan R Rd
11.	604	Noida Depot
12.	569	Kalyan Puri
13.	1470	Nangoli
14.	96	Narela Mandi
15.	292	Burari Garhi
16.	1428	Kapasehra Border
17.	1429	Kanjhawla Mor
18.	1386	Daurala Border (W)
19.	1353	Alipur GT Rd
20.	1509	Tikri Border
21.	1015	Ghatorni Village
22.	1380	Dhansa Border
23.	82	Prehladpur Vill
24.	1285	Palam Village
25.	1416	IGI Airport
26.	996	Mandi Village
27.	634	Indira Puri JJ Coloney
28.	1355	Auchandi Border
29.	150	Bakhtawar Pur
30.	632	Borola Vill

Table 4.2: Hubs identified by distance criteria of 7.5km.

S.no	Code of the stop	Name of the stop
31.	1008	Dera Village
32.	1194	Ujwa
33.	1236	Shikar Pur
34.	424	East Jawahar Ngr
35.	161	Singhu Mor
36.	1169	Kair
37.	121	Nizampur Vill
38.	156	Hamid Pur Vill
39.	327	Naya Bans Vill
40.	1024	Rajokri Harijan Basti
41.	213	Govt Co-Ed Schl
42.	1245	Nanak Heri
43.	128	Tatesar Vill
44.	332	Rishi Dharmarth Clinic
45.	1201	Ghanan Hera Mor

the hub which lies in the exterior of the city. Graphical display of hub Ghanan Hera Mor(1201) with its stops in influence area and influence area is shown in Fig4.3. Total of 20 stops are influenced by hub(1201) which lies in the exterior of the city.

4.3.3 Generation of Inter hub routes.

The main objective of this model is to develop a efficient Transit system. After the identification of the major hubs or primary terminals, they should be connected with each other to increase the accessibility of all the stops in the network. Route Generation starts with the selection of terminals(hubs) from already identified hubs between which route should be generated. The methodology adopted for the selection of terminals is given in section(2.7.3.3)The selection of terminals is subjected to some constraints . The various constraints are:

* Inter hub demand should not be less than some minimum cutoff demand.

* The distance between the hubs (route length) should lie between some minimum and maximum distances.
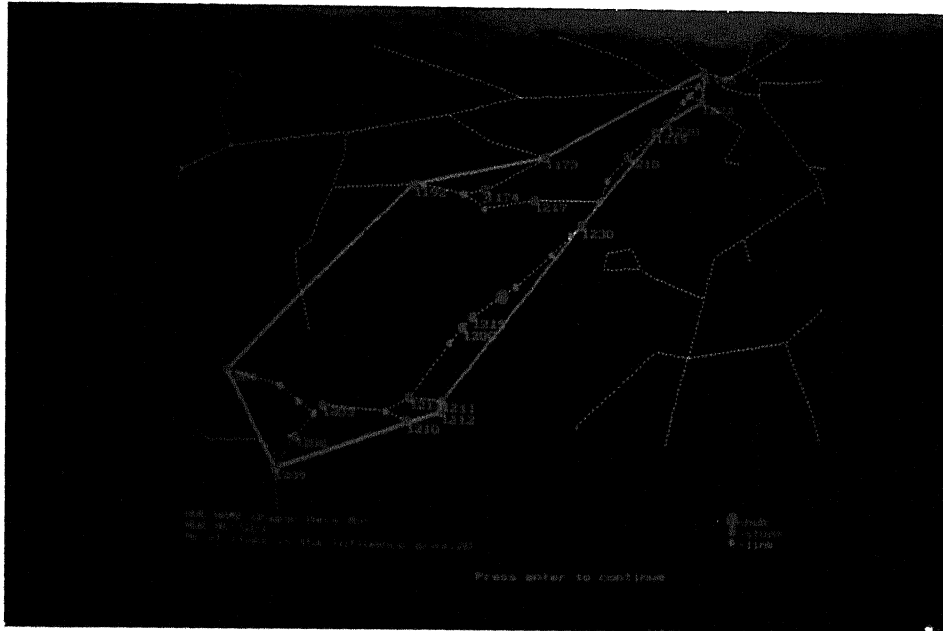
Figure 4.3: Graphical Display of hub(1201) with stops in its influence area.

Table 4.3: Stops influenced by a hub.

S.no	Stop code	Stop name
1.	1145	Jharodha Mor
2.	1173	Khera Dabar School
3.	1174	Khera Dabar
4.	1192	Jafar pur
5.	1200	Sankent Marg School
6.	1203	Jhul Jhali
7.	1204	Sarjung Pur
8.	1208	Daurala School
9.	1209	Daurala Village
10.	1210	Ghuman Hera school
11.	1211	Ghuman Hera Village
12.	1212	Ghuman Hera
13.	1213	Ghuman Hera Temple
14.	1215	Hassan Pur
15.	1217	Khakhri Jat Mal
16.	1218	Khera Temple
17.	1219	Prem Ngr
18.	1220	R.M.S Public School
19.	1222	Krasham Model School
20.	1230	Pandwala Mor

After the selection of terminals various alternatives are generated by meandering along the shortest path.The methodology adopted for finding out the alternative routes is described in section(2.7.3.5). The Analysis of the alternatives routes is done by calculating various statistics. The various parameters calculated for each route are described in section(2.7.3.6). Based on selection criteria the best route is selected and finally the route will adopted only if demand served by the route is more than feasible demand. Table4.4 shows some inter hub routes generated between hubs which are at least 7.5km apart, with cutoff demand constraint of 500, minimum route length constraint of 10km and maximum length constraint of 30km and meandering factors adopted in the generation of alternatives is 1.25 times shortest path. Fig4.4 shows the graphical display of the route between the hubs Redfort(1489) and Lajpat Ngr(R Rd) Fruit Market(1442) along with stops through which route passes.
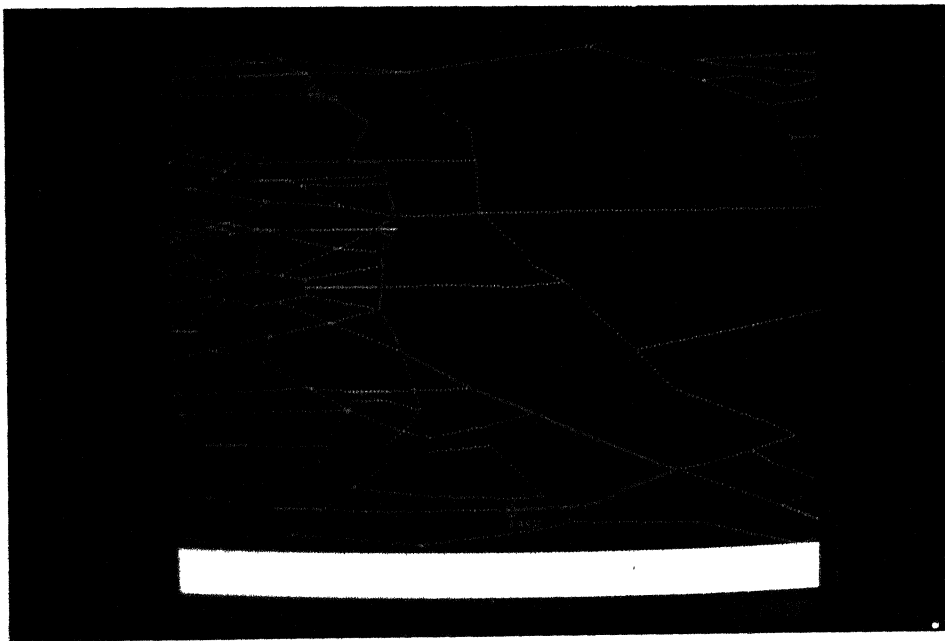
Figure 4.4: Graphical display of inter hub route between hubs(1489-1442)

4.3.4 Generation of feeder routes.

The stops which are influenced by a hub are connected to hub by feeder routes. The generation of feeder route between a stop and hub starts with generation of shortest path and then generating various alternatives by meandering along the

Table 4.4: Inter hub routes

Sno	HUBS		INTERMEDIATE NODES											Len(m)
1.	1442	1489	2324	1540	1539	2321	2320	1359	2319	773	1421	855	856	11669
			853	852	851	2648	645	644	1479	681	687	642	2116	
			1411	639	640	1390	660	1447	664	1392	1419			
2.	1463	1489	1463	2498	970	968	967	2492	2491	1531	2712	2481	964	20655
			2477	2473	2472	2461	2460	961	960	2459	957	2449	955	
			849	1361	2457	1461	2456	1442	2325	777	2331	2447	698	
			2330	2329	2328	696	2326	853	854	852	851	2648	645	
			644	1479	681	687	642	2116	1411	639	640	1390	660	
			1447	664	1392	1419								
3.	504	1489	1155	598	567	561	2241	560	557	590	595	1454	593	11366
			553	1441	541	542	1410	654	2120	660	1447	664	1392	
			1419											

shortest path. The methodology adopted for finding shortest path and generating various alternatives is described in section(2.7.3). Based on the selection criteria given in section(2.7.4) the best route is selected. Table4.5 shows some of the feeder routes generated for Lajpat Ngr RRd(1442) hub with meandering factor of 1.5 times shortest path. Fig4.5 shows the graphical representation of some of the feeder routes connecting hub(1442). A total of 19 feeder routes are generated to connect all the stops in the influence area of hub.

4.3.5 Scheduling.

The objective of this model is to estimate the number of bus trips on the generated feeder routes of a hub. The steps involved in the heuristic method are discussed in section(2.8). For the feeder routes selected demand is modified based on the stops in the influence of a hub. Passenger flow on various links, demand satisfied by each route and maximum number of bus trips on each route are determined.

For the first iteration of step1 the initial bus trips are made equal to assigned bus trips. The assigned trips for a link are revised based on the link flows of the route. The desired trips for a link are found out based on methodology described in the section(2.8.5). The final assigned bus trips should not be more than maximum bus trips on a route and less than minimum bus trips on a route. Table4.6 shows feeder routes connecting Redfort(1489) hub with details

Figure 4.5: Graphical display of feeder routes connecting hub(1442)

Table 4.5: Feeder routes connecting the hub 1442.

Hub	Path of the route									Route Length
1442	949	697	2329	2643	771	772	1421	773	2319	6806
	1359	2320	1358	647	1358	2320	2321	1539	1540	
	2324									
1442	1053	1046	2427	2425	1357	2450	848	2448	1514	4978
	849	1361	2457	1461	2456					
1442	1423	1391	697	2329	2330	698	2447	2457	1459	6692
	2455	1504	2454	749	748	749	2453	776	2324	
1442	964	2474	761	702	760	702	2555	701	2458	7137
	699	2455	1459	2457	1461	2456				
1442	695	944	2435	2440	697	1422	2444	953	954	7362
	849	955	2449	957	2449	955	849	1361	2457	
	1461	2456								
1442	882	1046	2427	2425	1357	2450	848	2448	1514	7315
	849	955	2449	957	2459	960	2459	957	2449	
	955	849	1361	2457	1461	2456				
1442	762	2558	2561	2559	2560	1466	754	752	753	5715
	784	785	786	787	2452	1396	776	2324		
1442	854	853	856	855	1421	773	2319	1359	2320	7057
	1358	647	860	647	1358	2320	2321	1539	1540	
	2324									

of demand served ,length and number of bus trips estimated with LOS-22.1 for each feeder route.

Table 4.6: Number of bus trips on feeder routes of hub(1489).

S.no	Stop No.	Demand Satisfied	Route Length(m)	Bus Trips
1	680	11816	5249	196
2	364	11744	7359	195
3	722	2601	6611	43
4	721	11798	6219	196
5	1450	3258	6734	54
6	1375	11509	5966	191
7	230	1626	6549	30
8		1989	5229	33
9	645	11778	5949	196
10	458	1626	4089	30
11	1066	12010	7049	200
12	363	1626	4997	30
13	179	1693	5611	30
14	858	11732	6305	195
15	674	11816	6441	196
16	1062	1626	4939	30
17	1074	11778	5478	196
18	1410	11778	4682	196
19	1519	1626	4424	30
20	222	1626	4622	30
21	669	11816	4135	196
22	672	11778	3737	196
23	656	1626	3390	30

4.3.6 Analysis of results.

4.3.6.1 Identification of hubs.

As described in section(2.4) the hubs are identified based on the production at the stop and the distance between the hubs should not be less than distance criteria.. Table4.7 shows number of hubs identified based on the distance criteria.

The results show that the number of hubs identified changes with the distance criteria. As expected the results in Table4.7 show that as distance in-

Table 4.7: Number of hubs identified based on distance criteria.

S.no	Min Dist(Km)	No. of hubs
1.	5.0	86
2.	6.0	65
3.	7.0	49
4.	7.5	45
5.	8.0	39
6.	8.5	33
7.	9.0	31
8.	9.5	27
9.	10.0	25

creases the number of hubs identified decreases.

4.3.6.2 Identification of stops influenced by a hub.

The number stops influenced by a hub depends upon the influence area and spatial distribution of stops. Influence area is selected based on the location of the stop. The number of stops influenced by a hub increases as influence area increases. Table4.8 shows the number of stops influenced and number of feeder routes generated for 1442 hub with different influence areas.

Table 4.8: Number of stops influenced and feeder routes generated for different influence area.

S.no	Influence area	No. of stops	No. of feeder routes
1.	5.0	.82	19
2.	6.0	120	24
3.	6.5	149	28

4.3.6.3 Generation of inter hub routes.

After the identification of primary terminals (hubs) these are connected by inter hub routes. The routes are generated by selecting two hubs at a time. After the selection of terminals, shortest path between the hubs is found and various alternatives are generated by meandering along the shortest path as described in section(2.7.3.5). Then analysis of various paths is done to estimate the various statistics.

Table 4.9: Number of inter hub routes with constraints.

S.no	Distance criteria(m)	Meandering Factor	Mini-Dem hubs	Min route Length(m)	Max route Length(m)	No of Routes
1.	5000	1.1	300	8000	25000	423
2.	5000	1.1	500	10000	30000	397
3.	5000	1.25	300	8000	25000	433
4.	5000	1.25	500	10000	30000	401
5.	7500	1.25	500	10000	30000	209

Table4.9 shows the number of inter hub routes generated for hubs identified by distance criteria of 5.0km and 7.5km with different meandering factor, demand and route length constraints. The results show that with the increase of meandering factor more number of inter hub routes are generated. This is because as meandering factor increases more number of alternatives are generated for hubs selected for route generation, which increases the number of inter hub routes generated. The results also show that with incresese of minimum demand between the hubs the number of inter hub routes generated decreseas as expected.

Table4.10 gives the details of various alternatives between the hubs(1489 and 1442). Based on the selection criteria by analyzing the alternatives the route having maximum desired passenger time per unit length is selected. In the above case alternative no.(16) is selected.

4.3.6.4 Generation of feeder routes connecting hub.

After the identification of stops influenced by a hub. These stops are provide accessibility by feeder routes. Feeder routes are generated by picking one stop at a time, till all the stops are connected to the hub. The process of generating route starts with the identification of shortest path between stop and hub and generating different alternatives by alternatives by meandering along the shortest path. These alternatives are evaluated and alternative having maximum value of demand per route length is selected.

Table4.11 shows the results of hubs identified by influence area of 7.5km. Total of 1382 stops are influenced by all the hubs. Maximum number of stops 299 are influenced by hub number 1489, Maximum number of feeder routes 37 are in the influence area of hub 1387. Maximum number of inter hub routes 29 originating from hub number 1489. The results show that number of stops

Table 4.10: Statistics of alternatives paths of inter hub route between(1489-1442)

Alt No.	Route length (m)	Route Travel time (sec)	Dem. satisf-ied	Av. Link Flow.	Route utiliz. coeff.	Actual Pass. Time	Actual Pass.Tm per unit (Pass_Kilo sec)	Desired Pass. Time	Desired Pass.Tm per unit
1	11462	1902	606984	340423	0.635	671427	353011	591710	311099
2	12320	1667	496182	309446	0.759	513472	308021	503213	301867
3	11711	1954	586184	333024	0.630	675003	345447	580527	297097
4	12464	1631	388564	299555	0.815	474073	290664	474073	290664
5	13264	2626	496108	318922	0.731	899218	342429	589451	224467
6	13168	2449	536686	321660	0.655	814749	332686	581851	237587
7	12941	2211	474116	310567	0.752	704317	318551	526051	237924
8	13360	2311	549816	333082	0.670	788804	341326	588013	254441
9	11975	2000	595954	334432	0.623	696723	348362	589384	294692
10	12070	1986	575490	325193	0.619	672622	338682	572217	288125
11	13277	2487	638854	362727	0.597	905499	364093	668743	268895
12	13858	2630	642354	364360	0.588	948303	360572	672240	255604
13	14127	2801	705568	386601	0.557	1051551	375420	727956	259891
14	14132	2639	643694	372124	0.586	953088	361155	676226	256243
15	14010	1978	682948	346556	0.653	717409	362694	610064	308425
16	11669	1702	656754	351360	0.666	630223	370284	610739	358836
17	13391	1881	689630	346824	0.655	684588	363949	613387	326096
18	18	2149	613624	336651	0.627	748497	348300	596809	277715
19	14198	2499	643732	369951	0.593	914233	365840	676270	270616
20	13576	2448	631190	367578	0.598	885777	361837	662031	270438
21	13024	2250	582772	321680	0.602	753087	334706	581182	258303
22	13701	2366	569904	315407	0.593	770389	325608	569235	240589
23	13812	2566	570774	344113	0.636	885268	344999	617212	240535
24	13587	2679	691144	340310	0.565	998617	372758	665296	248337
25	13270	2767	542198	323616	0.701	995236	359681	626004	226239
26	13867	2881	609624	325006	0.621	1039390	360774	628326	218093
27	14201	2993	641410	332588	0.602	1103551	368711	639733	213743
28	12568	2076	508438	316710	0.713	678156	326665	543009	261565
29	12620	2196	471586	302014	0.714	683281	311148	520748	237135
30	12936	2212	494910	310906	0.700	709503	320752	538919	243634
31	13250	2427	450318	290374	0.695	722948	297877	504822	208003
32	13996	2469	569192	315062	0.589	797255	322906	568503	230256
33	12064	2003	611880	337548	0.633	704496	351720	595393	297250
34	14190	2381	570502	313357	0.593	775059	325518	569730	239282

Table 4.11: Results of hubs identified by distance criteria of 7.5km.

S.no	Hub	No of stops influenced	No of feeder routes	No of routes originating
1	1489	113	23	29
2	1442	82	19	19
3	1350	118	24	24
4	1508	89	17	21
5	1469	57	16	15
6	1463	56	12	18
7	460	121	24	16
8	1373	20	6	11
9	1367	24	8	9
10	1387	97	20	20
11	604	37	11	11
12	569	71	16	16
13	1470	38	11	20
14	96	29	8	8
15	292	57	12	15
16	1428	25	5	11
17	1429	38	8	9
18	1386	13	4	5
19	1353	34	10	10
20	1509	15	7	5
21	1015	22	6	9
22	1380	12	3	3
23	82	49	12	13
24	1285	52	14	13
25	1416	11	4	4
26	996	11	3	3
27	634	51	10	18
28	1355	15	5	5
29	150	12	6	5
30	632	11	4	2
31	1008	17	4	6
32	1194	28	8	2
33	1236	15	6	2
34	424	33	7	14
35	161	6	2	2
36	1169	18	5	2
37	121	8	2	0
38	156	5	2	2
39	327	8	4	2
40	1024	12	3	5
41	213	15	5	2
42	1245	15	3	2
43	128	18	4	7
44	332	9	2	2
45	1201	20	5	1

influenced and of feeder routes connecting hub depend mostly on spatial distribution of stops and production at the stops.

Chapter 5

Summary of conclusions

5.1 Model development.

In this study an attempt has been made to develop an interactive hub and spoke model for bus transit network. The graphics capabilities developed can be used to understand the problem well.

The entire model is divided into following submodels. Identification of hubs, identification of stops under the influence area of a hub, generation of inter hub routes, generation of feeder routes connecting hub and scheduling of bus trips on the feeder routes.

The hub identification submodel identifies the hubs based on production at the stop and distance criteria. The influence area submodel identifies the stops which influenced by a hub based on influence area criteria.

The submodel of inter hub route generation starts with the selection of terminals for the route based on minimum demand and distance between the hubs. Then alternate paths are generated by meandering along the shortest path. The various alternatives are selected only if demand per route length of the alternative is more than demand per route length of the shortest path. Then these alternatives are evaluated by calculating route utilization co-efficient and desired passenger time per unit travel time to select the best. Finally the route will be adopted only if demand served by the route is more than feasible demand.The feeder route submodel generates feeder routes connecting hub. It selects a stop and generates alternative paths between stop and hub by meandering along the shortest path. Then the alternatives are evaluated by calculating demand per unit length and alternative with maximum value of

demand per route length is selected.

Scheduling submodel estimates the number of bus trips on a feeder route.Scheduling model starts with assigning of minimum and additional bus trips on each route.Link load or link flow on each link and maximum number bus strips on each route are estimated. Then number of trips on a route are revised based on the link flows on the various links of the route.The number of trips on a route are constrained to maximum and minimum numbers of bus trips estimated.

5.2 Use of Model

The data required for the practical problem will be of very big size. The input for the programmes is read from different files. If user wishes to have a graphical display,then the layout of the nodes are needed.

The user can enter the distance criteria of his choice and based on the distance criteria,the program identifies the primary hubs.If the user wishes, then he can include other stops as hubs.The user can also enter the influence area of his choice.All the results like hubs,stops in the influence area,details of routes(demand served,route length,path of the route),number of bus trips etc are stored in output files. In graphical display,the user can view the option of his choice.

5.3 Case study

1. The case study of Delhi metropolitan is divided into 47 zones.There are 1542 stops in total and 6327 links in the study area.The network is completely digitized for all nodes and links

2. The hubs are selected based on production at the stop and distance criteria. A total of 86 stops are identified as hubs for distance criteria of 5km, 45 by distance criteria of 7.5km and 25 by distance criteria of 10km.

3. The stops influenced by a hub vary according to the influence area and location of the hub. The maximum number of stops are influenced by hub number 1489 and minimum number of stops by hub number 156.

4. The hubs are connected to each other by inter-hub routes.The inter-hub

routes generated depend upon minimum demand and distance between the hubs. A total of 209 inter hub routes are generated for hubs identified by distance criteria of 7.5 kilometers.

5. The number of inter hub routes generated for hubs identified by distance criteria of 5.0 km differ with different meandering factor,demand and route length constraints. 423 routes are generated for meandering of 1.1, minimum distance between hubs 300 and route length constraints of 8000 and 25000, 397 routes for menadering of 1.1, demand 500 and route length constraints of 8000 and 25000. 433 routes for meandering of 1.25, demand 300 and route length constraints of 10000 and 3000, 401 routes for meandering of 1.25, demand 500 and route length constraints of 10000 and 30000.

6. The number of inter hub routes originating from a hub significantly differ. The number of originating routes depend upon the spatial distribution of hubs and production at the hub. The maximum number of routes originating from a hub identified by distance criteria of 7.5km are 29 and minimum are 1.

7. All the stops in the influence area of a hub are connected to a hub by feeder routes.The number of feeder routes in the influence area of a hub depend upon the number of stops in the influence area and the spatial distribution of these stops. Maximum number of feeder routes generated for hub identified by distance criteria of 7.5km are in the influence area of hub number 1489.

8. All the hubs,inter hub routes,influence area of the hub with the stops influenced by the hub and feeder routes are displayed so that,one can understand the entire bus transit system in a better manner.

9. The number of bus trips on all the feeder routes are estimated.These trips depend upon the demand served by the route,link flow on links of the route, average bus load for level of service.

5.4 Scope for future work

1. The model for feeder route generation may not find all the alternative routes.The programme could be modified to incorporate other alternative routes explicitly.

2. The program considers the demand matrix for bus transit only, but does not take into consideration the impact of other nodes.The routing and scheduling on feeder routes is done for desired trip matrix,further refinement of the suggested model may take care of the stochastic variations in travel demand.

3. Scheduling of feeder routes only estimates the bus trips. Operation headways can be found and time-table preparation can be done. Methodology for scheduling scheme on inter hub routes can be developed.

4. The main drawback of the program is that it can take decisions on it own. The program can be modified into an expert system to design the entire network.

5. The model could be made to include transfer demand also. Whereby, the demand from nodes which are not connected to the network can be transferred to the near by nodes,which are on the route network.

6. The cost of operation,the operator cost and passenger riding time cost can be included in the model to make it much more realistic.

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Appendix A

Results

Table A 1: Stops influenced by hubs of distance criteria of 7.5km.

Hub	Tt .Sts.	Stops in the influence area of a hub										
1489	113	26	179	184	185	217	218	219	220	221	222	223	224
		225	226	230	301	302	303	304	305	306	345	346	347
		362	363	364	458	459	515	639	640	642	643	644	645
		654	655	656	657	660	661	662	663	664	665	666	667
		668	669	670	671	672	673	674	675	680	681	682	683
		684	685	686	687	721	722	858	1061	1062	1064	1065	1066
		1067	1068	1069	1071	1072	1074	1362	1366	1370	1375	1384	1390
		1391	1392	1397	1403	1410	1411	1412	1413	1414	1417	1419	1435
		1436	1447	1450	1451	1453	1457	1467	1468	1474	1479	1490	1494
		1496	1497	1498	1507	1519							
1112	82	647	648	695	696	697	698	699	700	701	702	703	748
		749	750	751	752	754	755	760	761	762	768	769	770
		771	772	773	776	777	787	848	849	853	854	855	856
		860	861	862	863	866	867	868	869	870	882	883	896
		911	949	951	952	953	954	955	957	958	959	960	961
		964	1046	1053	1357	1358	1359	1361	1394	1396	1421	1422	1423
		1433	1459	1461	1466	1504	1514	1530	1538	1539	1540		
1350	118	1	2	3	4	9	10	11	12	13	14	15	16
		45	46	57	58	59	60	61	62	63	64	65	66
		67	68	69	70	72	180	182	216	229	230	231	232

		233	234	235	236	237	238	239	240	243	244	245	246
		272	277	278	279	280	281	282	283	284	285	286	287
		288	289	300	304	313	314	323	324	325	336	337	338
		341	343	344	345	346	348	349	350	351	352	353	354
		361	368	379	381	382	383	384	385	386	387	388	389
		390	391	392	1349	1351	1352	1356	1368	1371	1375	1405	1415
		1417	1425	1450	1451	1452	1483	1484	1485	1506	1523		
1508	89	18	35	36	44	186	307	322	339	340	342	359	380
		1060	1070	1073	1075	1076	1079	1094	1095	1096	1097	1098	1099
		1100	1101	1102	1103	1104	1105	1106	1107	1108	1109	1110	1111
		1112	1113	1114	1115	1116	1117	1118	1119	1120	1121	1122	1123
		1124	1125	1126	1127	1128	1129	1130	1131	1228	1258	1283	1298
		1300	1	1321	1327	1329	1330	1331	1332	1335	1336	1337	1338
		1339	1340	1341	1342	1343	1344	1345					
1469	57	1134	1135	1136	1137	1138	1139	1140	1141	1142	1143	1144	1145
		1146	1147	1148	1149	1150	1151	1152	1153	1159	1160	1161	1162
		1163	1164	1165	1166	1167	1168	1170	1171	1172	1217	1218	1219
		1220	1221	1222	1223	1224	1225	1226	1227	1229	1230	1233	1240
		1241	1242	1246	1259	1260	1261	1262	1282	1511			
1463	56	713	822	823	824	825	826	828	829	830	831	832	833
		834	836	837	838	839	840	841	873	874	875	876	877
		878	879	880	885	886	887	888	956	963	964	966	967
		968	969	970	971	972	973	974	975	987	988	997	998
		999	1000	1049	1377	1407	1456	1515	1531		-		
160	121	326	394	395	396	397	398	399	400	401	402	403	404
		405	406	407	427	428	429	430	431	432	433	434	435
		436	437	438	439	440	441	442	443	445	446	447	448
		449	450	451	452	453	454	455	456	458	459	461	462
		463	464	466	467	468	469	470	471	472	473	474	476
		477	478	479	480	481	482	483	484	485	486	487	488
		489	490	491	492	494	495	496	497	498	499	500	501
		502	503	504	505	506	507	508	509	510	511	512	514
		516	522	523	524	525	527	545	546	547	548	551	1363
		1364	1365	1434	1439	1440	1471	1501	1502	1518	1525	1526	1527
		1541											
1373	20	779	780	782	788	789	790	791	792	793	794	795	796
		797	798	799	800	801	802	803	1528				
1367	24	85	86	87	88	89	90	91	92	93	131	167	168
		169	170	171	172	173	174	175	176	177	178	187	1482

1387	97	199	204	227	228	290	658	719	736	805	806	807	808
		809	811	813	815	819	827	845	846	847	898	901	902
		903	904	905	906	907	908	909	910	911	912	913	915
		916	917	918	919	920	921	922	923	924	1025	1026	1027
		1028	1029	1030	1031	1032	1033	1034	1035	1036	1038	1039	1040
		1041	1042	1043	1044	1045	1046	1047	1048	1052	1054	1055	1056
		1057	1059	1304	1307	1308	1309	1310	1311	1312	1313	1318	1319
		1320	1322	1324	1328	1374	1388	1402	1458	1462	1465	1495	1537
		1538											
604	37	559	566	585	586	587	592	598	599	600	601	602	603
		605	606	607	608	609	610	611	612	613	614	615	616
		618	619	620	621	622	623	624	627	628	629	630	1516
		1517											
569	71	500	503	514	541	544	545	546	547	548	549	550	551
		553	554	555	557	558	559	560	561	562	563	564	565
		566	567	568	570	571	572	573	574	575	576	577	578
		579	580	581	582	583	585	586	587	588	589	590	591
		592	593	595	597	599	607	609	611	613	614	615	616
		618	619	620	621	1441	1454	1455	1503	1510	1516	1524	
1470	38	22	24	25	29	30	31	39	40	138	139	140	141
		142	143	144	145	146	200	201	202	203	205	208	355
		356	357	358	359	375	376	377	378	1155	1156	1157	1158
		1354	1477										
96	29	89	90	91	92	93	94	95	97	98	99	100	101
		102	103	104	105	106	159	160	162	163	164	165	166
		167	330	331	1448	1472							
292	57	4	5	72	73	74	75	76	78	109	110	111	112
		113	114	115	116	117	118	149	231	232	233	234	235
		236	237	238	239	240	241	242	243	244	245	246	247
		248	249	291	293	294	295	296	297	298	308	309	310
		311	386	1349	1356	1369	1405	1415	1484	1521			
1428	25	978	979	980	983	984	985	986	1019	1021	1022	1023	1247
		1248	1249	1250	1251	1253	1254	1255	1256	1257	1270	1271	1302
		1303											
1429	38	84	85	86	87	120	122	123	124	125	126	127	133
		134	135	136	137	138	139	188	189	190	191	192	193
		194	195	196	197	198	205	206	207	208	373	374	375
		376	377										

1386	13	1200	1203	1204	1205	1206	1207	1208	1209	1210	1211	1212	1213
		1215											
1353	34	5	72	73	74	75	76	101	102	103	104	105	106
		107	108	109	110	111	112	113	114	115	157	158	159
		160	163	273	274	275	276	296	333	1349	1521		
1509	15	119	120	122	137	201	205	206	208	209	210	211	212
		214	215	1161									
1015	22	804	972	973	974	975	987	988	989	990	991	992	993
		994	997	998	999	1014	1016	1017	1018	1377	1534		
1380	12	1177	1180	1181	1182	1183	1184	1185	1186	1187	1188	1189	1190
82	49	4	5	6	7	8	72	73	74	75	76	77	78
		79	80	81	83	84	85	86	87	112	113	114	250
		252	253	254	255	256	257	258	259	260	261	262	263
		264	265	266	267	268	269	270	271	272	334	335	1349
		1368											
1285	52	1252	1262	1263	1264	1265	1266	1267	1268	1269	1272	1273	1274
		1275	1276	1277	1278	1279	1280	1281	1282	1284	1286	1287	1288
		1289	1290	1291	1292	1293	1294	1295	1296	1297	1298	1301	1305
		1314	1315	1331	1332	1333	1334	1336	1337	1338	1339	1340	1341
		1342	1344	1481	1536								
1416	11	1020	1252	1266	1272	1274	1275	1277	1278	1286	1295	1299	
996	11	988	989	990	991	992	993	994	995	1002	1003	1017	
634	51	186	228	290	299	360	380	393	444	475	493	584	633
		635	636	637	638	641	646	653	658	659	689	691	718
		724	728	732	739	744	745	746	758	810	835	859	897
		902	904	1081	1091	1092	1093	1094	1095	1389	1395	1427	1446
		1460	1499	1535									
1355	15	88	89	129	130	131	167	168	170	171	172	173	174
		175	176	1482									
150	12	115	116	117	118	148	149	151	152	153	154	155	296
632	11	610	611	612	613	617	618	619	620	621	622	623	
1008	17	990	991	992	999	1000	1001	1002	1003	1004	1005	1006	1007
		1009	1010	1011	1012	1013							
1194	28	1163	1168	1170	1171	1172	1173	1174	1175	1176	1177	1178	1179

		1180	1181	1182	1183	1191	1192	1193	1195	1196	1197	1198	1199
		1202	1217	1218	1230								
1236	15	1214	1216	1229	1231	1232	1233	1234	1235	1237	1238	1239	1241
		1242	1243	1244									
424	33	399	400	401	402	403	404	405	406	407	408	409	410
		411	413	414	415	416	417	418	419	420	421	422	423
		425	426	427	445	446	457	1363	1364	1439			
161	6	159	160	162	163	164	165						
1169	18	1143	1144	1145	1146	1147	1163	1168	1170	1171	1172	1173	1175
		1176	1191	1193	1219	1220	1222						
121	8	119	120	122	194	209	210	211	215				
156	5	157	158	159	160	163							
327	8	88	89	90	167	168	274	276	333				
1024	12	979	980	983	984	985	986	1019	1021	1022	1023	1256	1257
213	15	119	120	137	201	205	206	208	209	210	211	212	1150
		1151	1159	1161									
1245	15	1214	1231	1233	1234	1235	1237	1238	1239	1240	1241	1242	1243
		1244	1246	1247									
128	18	122	123	124	125	126	127	129	130	131	172	173	174
		175	191	192	193	194	1482						
332	9	90	91	92	93	94	328	329	330	331			
1201	20	1145	1173	1174	1192	1200	1203	1204	1208	1209	1210	1211	1212
		1213	1215	1217	1218	1219	1220	1222	1230				

Table A.2: Interhub routes generated between hubs identified by distance of 7.5km.

Node From	Node To	Intermeadiate Nodes.										Route Len(m)
1442	1489	2324	1540	1539	2321	2320	1359	2319	773	1421	855	856	11669
		853	854	852	851	2648	645	644	1479	681	687	642	
		2116	1411	639	640	1390	660	1447	664	1392	1419		
1463	1489	2498	970	968	967	2492	2491	1531	2712	2481	964	2477	20655
		2473	2472	2461	2460	961	960	2459	957	2449	955	849	
		1361	2457	1461	2456	1442	2325	777	2331	2447	698	2330	
		2329	2328	696	2326	853	854	852	851	2648	645	644	
		1479	681	687	642	2116	1411	639	640	1390	660	1447	
		664	1392	1419									
569	1489	1455	568	567	561	2241	560	557	590	1454	593	553	11366
		1441	541	542	1410	654	2120	660	1447	664	1392	1419	
1489	1508	1419	1392	664	1447	666	2114	661	1457	665	667	2115	
		212	2649	2714	1496	1497	1498	1494	1474	1420	733	729	
		1360	1473	2145	725	1393	2654	2138	2079	902	2075	859	
		1395	718	2061	724	1389	2059	1499	691	2049	360	1460	
		1094	1095	2050	1096	1097	1491	1098	2678	1493	1101	1106	·
		1107	1110	1115	1117								
634	1489	2054	635	636	2621	689	1395	859	2075	902	2079	2138	13241
		2654	1393	931	727	2687	1372	734	729	733	1420	1474	
		1494	1498	1497	1496	2714	2649	2122	2115	667	665	1457	
		661	2114	666	1447	664	1392	1419					
1387	1489	2377	907	1059	2380	2379	1048	910	908	909	911	1047	12712
		2134	912	1038	2140	2659	1393	931	727	726	2687	1372	
		734	729	733	1420	1474	1494	1498	1497	1496	2714	2649	
		2122	2115	667	665	1457	661	2114	666	1447			
460	1350	452	1502	456	453	454	455	1501	458	2203	2188	2619	13708
		515	1413	2625	226	303	302	304	2003	1450	2001	231	
		1415	232	1405	1356	300	2012	379	1350				
1470	1489	1727	358	1477	25	1706	24	1701	1520	1704	1711	1954	21820
		1957	1449	1955	16	1977	14	59	60	64	1352	1985	
		2015	1350	1990	341	289	337	336	57	1483	343	344	
		1506	1998	1375	345	1417	1507	347	219	218	2087	2088	
		185	1397	1435	1490								
1373	1489	793	2604	2595	792	791	790	788	2582	1532	866	1530	23337
		870	869	868	867	2706	786	787	2452	1396	776	2324	
		1442	2456	1461	2457	1361	849	954	953	2444	1422	697	
		2440	2435	944	695	2434	694	851	2648	645	644	1479	
		681	687	642	2116	1411	639	640	1390	660	1447	664	
		1392	1419										
1350	1508	1990	341	289	337	336	57	1483	343	344	1506	1998	14954

		2027	368	369	370	321	315	2034	1088	316	1089	1090	
		1091	1092	1427	360	1460	1094	1095	2050	1096	1097	1491	
		1098	2678	1493	1101	1106	1107	1110	1115	1117			
424	1489	426	423	420	421	2350	2351	2352	2353	1363	2354	408	12083
		2355	2204	459	2618	2192	1490						
1469	1489	1875	1141	1876	1140	1139	1138	1137	1136	1135	1134	1511	29706
		2640	1338	1122	1784	1321	1767	1121	1385	1120	1119	1769	
		1118	1508	1117	1115	1110	1107	1106	1101	1493	2678	1098	
		1491	340	2045	2044	2043	342	1476	1553	1475	1371	46	
		58	59	60	64	1352	1985	2015	1350	1990	341	289	
		337	336	57	1483	343	344	1506	1998	1375	345	1417	
		1507	347	219	218	2087	2088	185	1397	1435	1490		
292	1489	291	1942	248	2022	247	2018	241	240	239	244	238	13691
		237	235	234	233	1484	232	1415	231	2001	1450	2003	
		304	302	303	226	225	2090	301	2187	2624	1403	2189	
		2191	1490										
1350	1442	379	2012	300	1356	1405	232	1415	231	2001	1450	2003	20695
		304	302	2089	226	225	2090	301	2187	2624	1403	2189	
		2191	1490	1489	1419	1392	664	1447	660	1390	640	639	
		1411	2116	642	687	681	1479	644	645	2648	851	852	
		854	853	2326	696	2328	2329	2330	698	2447	2331	777	
		2325											
82	1489	81	79	1934	78	1935	76	75	74	1933	73	72	19007
		1349	4	1961	1425	1962	2	1351	2013	1350	1990	341	
		289	337	336	57	1483	343	344	1506	1998	1375	345	
		1417	1507	347	219	218	2087	2088	185	1397	1435	1490	
1442	1508	2456	1461	2457	1361	849	1514	2448	848	2450	1357	2425	19185
		2427	1046	1538	1374	1045	1044	1043	2417	1462	901	1465	
		2392	903	1387	2377	906	2375	199	1322	204	2368	227	
		2365	1328	2370	1324	2679	1327	1445	1131	1773	1228	1258	
		1119	1769	1118									
604	1489	603	2699	1516	2284	580	2289	2282	2260	565	2280	562	17708
		2259	569	1455	568	567	561	2241	560	557	590	595	
		1454	593	553	1441	541	542	1410	654	2120	660	1447	
		664	1392	1419									

634	1350	2054	635	636	2621	689	1395	732	739	744	745	2068	13821
.		1383	1086	1084	1487	1087	2036	2033	1857	2032	370	369	
		368	2027	1998	1506	344	343	1483	57	336	337	289	
		341	1990										
1387	1463	903	2392	1465	901	1462	2417	1043	1044	1045	1374	1538	11120
		1046	2427	883	881	884	2429	1049	1407	2479	836	2482	
		833	834	2492	967	968	970	2498					
569	1350	1455	568	567	561	2241	560	557	590	595	1454	593	20080
		553	1441	541	542	1410	654	2120	660	1447	664	1392	
		1419	1489	1490	1435	1397	185	2088	2087	218	219	347	
		1507	1417	345	1375	1998	1506	344	343	1483	57	336	
		337	289	341	1990								
460	1442	452	1502	456	453	454	455	1501	458	2203	2204	2188	20326
		2619	515	1413	1414	2187	2624	1403	2189	2191	1490	1489	
		1419	1392	664	1447	660	1390	640	639	1411	2116	642	
		687	681	1479	644	645	2648	851	852	854	853	2326	
		696	2328	2329	2330	698	2447	2331	777	2325			
1350	1387	1990	341	289	337	336	57	1483	343	344	1506	1998	17405
		1375	345	1417	1507	347	219	217	2037	1064	1062	1082	
		1063	1398	1426	1424	1378	935	2080	1404	2105	2106	932	
		2687	726	727	931	1393	2659	2140	913	1038	912	2134	
		1047	911	909	908	910	1048	2379	2380	1059	907	2377	
569	1442	1455	563	1510	2242	591	557	2276	2668	2665	2664	648	12054
		647	1358	2320	2321	1539	1540	2324					
424	1350	426	411	2339	417	416	410	2346	409	2354	408	2355	16195
		2337	311	2008	2627	304	2003	230	182	181	180	183	
		179	1451	346	1417	345	1375	1998	1506	344	343	1483	
		57	336	337	289	341	1990						
460	1387	452	1502	456	453	454	455	1501	458	2618	2192	1490	19232
		1489	1419	1392	664	1447	666	2114	1391	2097	2100	2101	
		2650	2119	2162	720	2168	2651	2178	2150	925	1430	2658	
		1438	2152	2158	2399	918	919	2394	909	908	910	1048	
		2379	2380	1059	907	2377							
1429	1489	1638	86	87	1661	1660	84	1662	83	1663	82	81	28710
		79	1934	78	1935	76	75	74	1933	73	72	1349	
		4	1961	1425	1962	2	1351	2013	1350	1990	341	289	
-		337	336	57	1483	343	344	1506	1998	1375	345	1417	
		1507	347	219	218	2087	2088	185	1397	1435	1490		
1015	1489	1016	1534	2519	2512	2510	987	2505	973	1463	2498	970	29049

		1461	2456	1442	2324	1540	1539	2321	2320	1358	647	648	
		2664	2665	2668	649	594	650	652	1410	654	2120	660	
		1447	664	1392	1419								
292	460	1369	1941	249	2021	2020	309	308	311	2337	2355	408	15837
		2354	409	1363	1364	406	445	2244	448	2245	431	1365	
		432	452										
1285	1489	1263	1797	1799	1798	1280	1788	1786	1481	2640	1338	1122	23828
		1784	1321	1767	1121	1385	1120	1119	1769	1118	1508	1117	
		1115	1110	1107	1106	1101	1493	2678	1098	1491	1097	1096	
		2050	1095	1094	1460	360	1427	1092	1091	1090	1089	316	
		1088	2034	315	321	370	363	217	219	218	2087	2088	
		185	1397	1435	1490								
96	1350	1573	1576	1577	1579	105	106	1602	1600	107	1353	108	19035
		1921	1923	109	110	111	112	1927	113	1928	5	72	
		1349	4	1961	1425	1962	2	1351	2013				
1428	1489	1256	1257	1021	1881	1019	1882	1883	1550	1557	1303	1026	25150
		2681	1304	1027	2389	1316	2381	2713	1025	719	1388	2377	
		907	1059	2380	2379	1048	910	908	909	2394	919	918	
		917	2157	916	2153	2158	2152	1438	2658	1473	1360	729	
		733	1420	1474	1494	1498	1497	1496	2714	2649	2122	2115	
		667	665	1457	661	2114	666	1447	664	1392	1419		
460	1508	452	1502	456	453	454	455	1501	458	2618	2192	1490	23887
		1489	1419	1392	664	1447	666	2114	661	1457	665	667	
		2115	2122	2649	2714	2715	2093	2094	858	2092	857	850	
		935	2684	842	899	759	2070	2062	739	732	1395	718	
		2061	724	1389	2059	1499	691	2049	360	1460	1094	1095	
		2050	1096	1097	1491	1098	2678	1493	1101	1106	1107	1110	
		1115	1117										
82	1470	81	80	1938	267	269	1945	266	1947	335	1948	334	15179
		6	7	1449	1957	1954	1711	1704	1520	1701	24	1706	
		25	1477	358	1727								
634	1470	2054	1446	493	584	2060	633	2059	1499	691	2049	360	12827
		1460	1093	2038	42	2023	41	1726	40	1725	1723	1724	
		1477	358	1727									
634	1469	2054	635	636	2621	689	1395	2064	2063	1081	2067	728	24895
		2061	724	1389	2059	1499	691	2049	360	1460	1094	1095	
		2050	1096	1097	1491	1098	2678	1493	1101	1106	1107	1110	
		1115	1117	1508	1118	1769	1119	1120	1385	1121	1767	1321	
		1784	1122	1338	2640	1511	1134	1135	1136	1137	1138	1139	

		1140	1876	1141	1875								
1387	1469	2377	906	2375	199	1322	204	2368	2371	228	290	299	22272
		380	2052	1492	2051	1099	2678	1493	1101	1106	1107	1110	
		1115	1117	1508	1118	1769	1119	1120	1385	1121	1767	1321	
		1784	1122	1338	2640	1511	1134	1135	1136	1137	1138	1139	
		1140	1876	1141	1875								
460	634	452	1502	456	453	454	455	1501	458	2618	2192	1490	18547
		1489	1419	1392	664	1447	666	2114	661	1457	665	667	
		2115	2122	2649	2714	2715	2093	2094	858	2092	857	850	
		935	2684	842	899	759	2070	2062	739	732	1395	689	
		2621	636	635	2054								
460	604	452	2218	2214	482	483	484	2663	501	499	500	546	16459
		547	2228	514	550	2232	2233	2235	2238	558	595	590	
		557	560	2241	561	567	568	1455	569	2259	2258	2260	
		2282	2289	580	2284	1516	2699	603					
460	1470	452	1502	456	453	454	455	1501	458	2618	2192	1490	27402
		1489	1419	1392	664	1447	666	2114	661	1457	665	663	
		1362	1436	1467	1069	2085	1068·	1370	1065	1384	1061	362	
		364	367	2032	371	372	2034	1088	316	317	319	320	
		1475	43	42	2023	41	1726	40	1725	1723	1724	1477	
		358	1727										
634	1442	2054	635	636	2621	689	1395	732	739	2062	758	2069	18104
		1382	1077	1398	1426	1424	1378	935	850	857	2092	858	
		2094	1072	2108	1474	1494	722	2163	2170	2651	2165	2185	
		2180	2181	929	933	2644	678	679	2434	695	944	2435	
		2440	697	2329	2330	698	2447	2331	777	2325			
82	460	81	79	1934	78	1935	76	75	74	1933	73	72	29294
		1349	4	1961	1425	1962	2	1351	2013	1350	1990	341	
		289	337	336	57	1483	343	344	1506	1998	1375	345	
		1417	1507	347	219	218	2087	2088	2322	2084	1436	1362	
		663	665	1457	661	2114	666	1447	664	1392	1419	1489	
		1490	2192	2618	458	1501	455	454	453	456	1502	452	
1469	1470	1146	1149	1760	1759	1155	1156	1157	1742	1735	200		11576
1442	1470	2325	777	2331	2447	698	2330	2329	2328	696	2326	853	
		854	852	851	2648	645	644	1479	681	687	642	2116	
		1411	639	640	1390	660	1447	664	1392	1419	1489	1490	
		2191	2190	2619	515	2624	220	221	219	217	363	370	
		321	315	2034	1088	316	317	319	320	1475	43	42	
		2023	41	1726	40	1725	1723	1724	1477	358	1727		

96	1489	1573	1576	1577	1579	105	106	1602	1600	107	1353	108	27749
		1921	1923	109	110	111	112	1927	113	1928	5	72	
		1349	4	1961	1425	1962	2	1351	2013	1350	1990	341	
		289	337	336	57	1483	343	344	1506	1998	1375	345	
		1417	1507	347	219	218	2087	2088	185	1397	1435	1490	
1169	1508	1163	1168	1879	1871	1870	1145	1869	1144	1143	1142	1469	19757
		1875	1141	1876	1140	1139	1138	1137	1136	1135	1134	1511	
	.	2640	1338	1122	1784	1321	1767	1121	1385	1120	1119	1769	
		1118											
82	1508	81	80	1938	267	269	1945	266	1947	335	1948	334	19948
		6	7	1449	1955	16	53	1971	55	1974	56	1975	
		47	1371	1475	1553	1476	342	2043	2044	2039	1105	1103	
		2042	1493	1101	1106	1107	1110	1115	1117				
1373	1463	2605	798	2606	799	801	800	2543	1512	2545	2542	2541	13529
		872	714	2493	873	713	2494	2495	2489	885	2669	876	
		2496	880	969	971	2497	2498						
460	1463	452	1502	456	453	454	455	1501	458	2618	2192	1490	24143
		1489	1419	1392	664	1447	666	2114	661	1457	665	667	
		2115	2122	2649	2714	1496	1497	1498	1494	722	2622	2178	
		2177	2179	926	2160	940	2407	2639	2433	1058	743	1505	
		2414	2413	1409	2431	1431	775	2425	1443	881	884	2429	
		1049	1407	2479	836	2482	833	834	2492	967	968	970	
		2498											
569	1387	1455	568	567	561	2241	560	557	2276	2668	2665	2664	21149
		648	647	1358	2320	2321	1539	1540	2324	1442	2456	1461	
		2457	1361	849	1514	2448	848	2450	1357	2425	1443	881	
		883	2427	1046	1538	1374	1045	1044	1043	2417	1462	901	
		1465	2392	903									
292	569	291	1942	248	2022	247	2018	241	240	239	244	2006	24317
		243	1405	232	1415	231	2001	1450	2003	304	302	303	
		226	225	2090	301	2187	2624	1403	2189	2191	1490	1489	
		1419	1392	664	1447	660	1390	640	639	1411	2116	1412	
		1410	542	541	1441	553	593	1454	595	590	557	560	
		2241	561	567	568	1455							
1387	1428	903	2392	1465	901	1462	2416	1035	2415	1029	2708	2388	14882
		1028	1315	2389	1027	1304	2681	1026	1303	1557	1550	1883	
		1882	1019	1881	1021	1257	1256						

1442	1469	2456	1461	2457	1361	849	1514	2448	848	2450	1357	2425	29559
		2427	1046	1538	1374	1045	1044	1043	2417	1462	901	1465	
		2392	903	1387	2377	906	2375	199	1322	204	2368	2371	
		228	290	299	380	2052	1492	2051	1099	2678	1493	1101	
		1106	1107	1110	1115	1117	1508	1118	1769	1119	1120	1385	
		1121	1767	1321	1784	1122	1338	2640	1511	1134	1135	1136	
		1137	1138	1139	1140	1876	1141	1875					
82	1442	81	79	1934	78	1935	76	75	74	1933	73	72	30988
		1349	4	1961	1425	1962	2	1351	2013	1350	379	2012	
		300	1356	1405	232	1415	231	2001	1450	2003	304	302	
		2089	226	225	2090	301	2187	2624	1403	2189	2191	1490	
		1489	1419	1392	664	1447	660	1390	640	639	1411	2116	
		642	687	681	1479	644	645	2648	851	852	854	853	
		2326	696	2328	2329	2330	698	2447	2331	777	2325		
1350	1355	2015	1985	1352	64	60	59	58	46	1371	47	1975	31146
		56	1974	55	1971	53	16	1955	1449	7	6	334	
		1948	335	1947	266	1945	269	267	1938	80	81	82	
		1663	83	1662	84	1660	1661	87	85	1618	2630	88	
		1625	167	1620	1619	171	1626						
1350	1463	1990	341	289	337	336	57	1483	343	344	1506	1998	26148
		1375	345	1417	1507	347	219	218	2087	2088	185	1397	
		1435	1490	1489	1419	1392	664	1447	660	1390	640	639	
		1411	2116	642	643	684	2173	680	2182	2175	688	2180	
		2181	929	2183	2436	938	2639	2433	1058	743	1505	2414	
		2413	1409	2431	1431	775	2425	1443	881	884	2429	1049	
		1407	2479	836	2482	833	834	2492	967	968	970	2498	
1387	1470	2377	1388	719	2378	1310	1311	2373	1900	2369	2370	1324	18899
		2679	1327	1445	1775	1774	1408	1076	1770	1771	1111	1110	
		1115	1117	1508	1118	1769	1130	1129	1766	1128	2673	2674	
		1739	359	1477	358	1727							
1350	1367	2015	1985	1352	64	60	59	14	1977	16	1955	1449	24117
		7	6	334	1948	335	1947	266	1945	269	267	1938	
		80	81	82	1663	83	1662	84	1660	1661	87	85	
		1618	2630	88	1625	1622	168						
424	569	426	423	419	2349	401	400	1439	2359	428	429	434	16744
		433	430	460	452	2218	2214	482	483	484	2663	501	
		499	500	546	547	2228	545	548	2229	578	2255	579	
		589	2256	571	2258	2259							

Table A.3: Stastistics of selected inter hub routes of hubs identified by distance criteria of 7.5km.

Alt No.	Route length $\widehat{\mathrm{m}}$	Route Travel time (sec)	Dem.. Satisf- ied	Av. Link Flow.	Route utiliz. coeffient	Actual Pass. Time	Actual Pass.Tm per unit	Desired pass. Time	Desired pass.Tm per unit
							(pass_kilo sec)		
16	11669	1702	574916	255446	0.583000	469129	275634	456787	268382
59	20655	3055	783628	263075	0.512000	870110	284815	758000	248118
1	11366	1709	344839	149851	0.676000	262542	153623	239832	140335
48	18919	2711	707548	209039	0.426000	588330	217016	549836	202817
14	13241	2101	537761	206398	0.457000	459618	218761	434595	206852
23	12172	1702	496247	184171	0.496000	396614	233028	393802	231376
1	13708	2551	330894	105295	0.567000	319492	125242	319492	125242
23	21820	3811	1032614	319235	0.517000	1235604	324220	936757	245804
24	23337	3025	823829	233461	0.478000	747427	247083	666256	220250
5	14954	2017	417252	132828	0.545000	251427	124654	239285	118634
14	12083	2520	98962	61530	0.640000	147084	58367	141521	56159
24	32706	5108	1381728	324194	0.493000	1738170	340284	1305242	255529
10	13691	2518	185197	90123	0.828000	237749	94420	214169	85055
64	20695	3380	1006758	321818	0.661000	1117248	330547	992399	293609
1	19007	3407	941675	297541	0.522000	1043139	175	806275	236653
4	19185	2220	593000	166607	0.418000	366674	165169	365018	164422
9	17708	4	406998	137667	0.511000	393272	128353	330381	107827
18	13821	2196	282667	96767	0.435000	204741	93234	185646	84538
9	11120	1344	208987	79215	0.572000	105706	78650	103605	77087
45	20080	3722	1107760	307525	0.539000	1172677	315066	909455	244346
' 45	20326	3836	1251025	320397	0.564000	1279943	333666	1093072	284951
57	17405	2644	272116	79587	0.359000	223924	84691	203109	76819
2	12054	1762	154633	57268	0.331000	67262	38174	65961	37435
2	16195	3396	284779	83908	0.264000	202558	59646	180409	53124
34	18232	3377	701758	174489	0.559000	798380	236417	777113	230119
15	28710	4448	950712	262879	0.428000	1134969	255164	881393	198155
9	29049	4212	723666	225740	0.489000	820048	194693	764550	181517
7	15837	3484	91192	34311	0.506000	142147	40800 .	106537	30579
71	23828	3913	541781	120588	0.393000	471845	120584	406554	103898
1	19035	2505	162282	52622	0.425000	118174	47175	116990	46703
47	25150	3437	448624	103486	0.240000	355280	103369	351214	102186
29	23887	4123	798415	161747	0.514000	853979	207126	827124	200612
2	15179	2059	178589	57979	0.613000	131838	64030	128630	62472
4	12827	1632	203148	61	0.441000	94818	58099	94818	58099
9	24895	3247	531651	130149	0.612000	435983	134273	290497	89466
8	22272	2527	241666	67160	0.506000	163600	64741	151948	60130
18	18547	3564	655483	153648	0.528000	744405	208868	725420	203541

Table A.4: Feeder routes connecting hub.

	Path of feeder route connecting hub.
Hub No : 1489	
1.	680 2173 684 643 642 682 642 2116 1411 639 640 1390 660 1447 664 1392 1419
2.	364 362 1061 1384 1065 1370 1068 2085 1069 1467 1436 1362 2112 2113 2111 1419
3.	722 1494 1474 2108 1072 2094 2093 1071 1467 1436 2084 2322 1397 1435 1490
4.	721 675 1498 1497 1496 2714 2715 2093 1071 1467 1436 1362 2112 2113 2111 1419
5.	1450 2003 304 302 303 226 226 2625 1413 1414 2187 1453 220 185 2191 1490
6.	1375 345 1417 1507 347 219 221 220 185 1397 1366 2111 1419
7.	230 182 181 180 183 2005 184 2086 219 218 2087 2088 185 2191 1490
8.	306 2250 305 2625 1413 515 2624 1403 2189 2191 1490
9.	645 644 683 684 2169 685 2118 2650 2101 2100 2097 1391 2114 666 1447 664 1392 1419
10.	458 2618 459 2618 2192 1490 1489
11.	1066 1067 2124 2085 1069 1467 1436 1362 663 665 1457 661 2114 666 1447 664 1392 1419
12.	363 217 219 221 26 2088 185 2191 1490
13.	179 1451 246 1417 1507 347 219 221 1490 1489
14 .	858 2092 1071 1467 1436 1468 1436 1362 2112 2113 2111 1419
15.	674 2110 2650 2118 686 642 687 681 1479 681 687 642 2116 1411 639 640 1390 660 1447 664
	1392 1419
16.	1062 1064 2037 217 219 221 220 185 2191 1490
17.	1074 1467 1436 1468 2115 667 668 673 661 2114 666 1447 664 1392 1419
18.	1410 1412 1410 654 2120 660 1447 664 1392 1419
19.	1519 1507 347 219 221 220 185 2191 1490
20.	222 223 224 225 2090 301 2187 1453 220 185 2191 1490
21.	669 2123 2096 2097 670 671 640 1390 660 1447 664 1392 1419
22.	672 670 2097 1391 2114 662 2114 666 1447 664 1392 1419
23.	656 655 656 657 2192 1490
Hub No : 1442	
1.	949 697 2329 2643 771 772 1421 773 2319 1359 2320 1358 647 1358 2320 2321 1539 1540 2324
2.	1053 1046 2427 2425 1357 2450 848 2448 1514 849 1361 2457 1461 2456
3.	1423 1394 697 2329 2330 698 2447 2457 1459 2455 1504 2454 749 748 749 2453 776 2324
4.	964 2474 761 702 760 702 2555 701 2458 699 2455 1459 2457 1461 2456
5.	695 944 2435 2440 697 1422 2444 953 954 849 955 2449 957 2449 955 849 1361 2457 1461 2456
6.	882 1046 2427 2425 1357 2450 848 2448 1514 849 955 2449 957 2459 960 2459 957 2449 955 849
	1361 2457 1461 2456
7.	960 2459 957 2449 955 849 1361 2457 1461 2456
8.	762 2558 2561 2559 2560 1466 754 752 753 784 785 786 787 2452 1396 776 2324
9.	854 853 856 855 1421 773 2319 1359 2320 1358 647 860 647 1358

10.	866 1530 870 869 868 867 2706 786 787 2452 1396 776 2324
11.	1538 1046 2427 2425 1357 2450 848 2448 1514 849 1361 2457 2447 2331 777 2325 770 2325
12.	755 1433 754 2563 751 768 751 750 748 749 2453 776 2324
13.	896 2438 2440 2439 696 2328 2329 2330 698 2447 2331 777 2325
14.	703 702 2555 701 2458 958 959 958 2458 699 2455 1459 2457 1461 2456
15.	883 2427 2425 1357 2450 848 2448 1514 849 1361 2457 1461 2456
16.	863 2315 862 861 860 647 1358 2320 2321 1539 1540 2324
17.	951 2466 2446 2441 1444 948 945 2642 2438 2440 697 1422 2444 952 2444 953 954 849 1361 2457
	1461 2456
18.	961 2460 700 2458 699 2455 1459 2457 1461 2456
19.	648 647 1358 2320 2321 1539 1540 2324
Hub No: 1469	
1.	1282 1809 1262 1137 1136 1135 1134 1511 1134 1135 1136 1137 1138 1139 1140 1876 1141 1875
2.	1172 1171 1170 1878 1168 1879 1871 1870 1145 1869 1144 1143 1142
3.	1233 1847 1848 1826 1224 1223 1874 1142
4.	1153 1152 1760 1149 1146
5.	1217 1833 1831 1218 1219 1220 1873 1872 1870 1145 1147 1145 1869 1146
6.	1161 1754 1159 1150 1151 1755 1160 1755 1146
7.	1167 1166 1867 1165 1148 1147 1145 1870 1872 1222 1872 1870 1145 1869 1146
8.	1241 1246 1240 1823 1226 1225 1224 1223 1874 1142
9.	1242 1827 1241 1246 1240 1823 1824 1227 1824 1823 1226 1225 1224 1223 1874 1142
10.	1230 1833 1831 1218 1219 1220 1873 1872 1870 1145 1869 1146
11.	1162 1753 1151 1755 1146
12.	1229 1848 1826 1224 1223 1874 1142
13.	1261 1259 1260 1259 1139 1140 1876 1141 1875
14.	1163 1168 1879 1871 1870 1145 1869 1146
15.	1221 1832 1877 1222 1872 1870 1145 1869 1146
16.	1164 1868 1871 1870 1145 1869 1146
Hub No : 96	
1.	167 89 1606 90 93 91 93 90 1578 94 1574 95 1573
2.	331 1604 330 92 90 1578 94 1575 1576 101 1572 97 1472
3.	162 1909 1564 163 164 165 1563 1569 97 1570 98 1571 99 1571 98 1570 97 1472
4.	159 1585 1567 160 1568 1566 1572 97 1472
5.	1448 100 1571 98 1570 97 1472 96
6.	104 1580 102 103 101 1576 1573
7.	106 105 1579 1577 1576 1573
8.	166 1563 1569 97 1472

Hub No : 1350	
1.	272 1368 1349 4 1961 3 1961 1425 1962 2 1351 2013
2.	9 10 1485 11 12 1968 13 1977 14 59 60 64 1352 1985 2015
3.	236 235 234 233 1484 232 1415 231 1415 232 1405 1356 300 2012 379
4.	392 368 2027 1998 1506 344 343 1483 57 336 337 289 341 1990
5.	283 284 285 1993 1995 286 278 1983 1984 277 1970 1352 1985 1523 61 2016 62 63 62 2016
	61 1523 1985 2015
6.	180 181 182 230 2003 1450 2002 229 2002 1450 2001 231 1415 232 1405 1356 300 2012 379
7.	45 46 351 2024 2025 350 325 348 352 324 1981 279 278 1983 1984 277 1970 1352 1985 2015
8.	16 1977 14 59 58 59 60 64 1352 1985 2015
9.	1451 346 1451 1999 389 1997 388 386 1405 1356 300 2012 379
10.	1371 46 58 59 60 64 1352 1985 2015
11.	216 361 2028 1998 1375 345 391 390 389 1997 388 386 1405 1356 300 2012 379
12.	313 2007 314 2001 231 387 231 1415 232 1405 1356 300 2012 379
13.	72 1349 4 1961 1425 1962 2 1 2 1351 2013
14.	70 69 68 1964 67 66 65 1965 1969 63 62 2016 61 1523 1985 2015
15.	304 2003 230 182 2000 1997 1452 1997 388 386 1405 1356 300 2012 379
16.	237 238 244 239 240 239 244 2006 243 1405 1356 300 2012 379
17.	1417 345 391 390 389 385 384 383 1996 1356 300 2012 379
18.	15 1968 13 1977 14 59 60 64 1352 1985 2015
19.	282 281 1982 323 353 324 352 1979 1983 1984 277 1970 1352 1985 2015
20.	349 350 325 348 352 324 353 280 1981 279 278 1983 1984 277 1970 1352 1985 2015
21.	354 1979 1983 1984 277 1970 1352 1985 2015
22.	288 287 286 1995 338 1995 286 278 1983 1984 277 1970 1352 1985 2015
23.	245 2011 246 1356 300 381 2010 379
24.	382 1989 289 341 1990
Hub No : 1508	
1.	36 2047 2048 35 1476 342 2043 2044 2045 340 1491 1098 2678 1493 1101 1106 1107 1110
	1115 1117
2.	1125 1765 1123 1124 1126 1127 1120 1385 1768 1346 1768 1385 1120 1119 1769 1118
3.	1335 1341 1340 1339 1338 1122 1784 1321 1767 1121 1385 1120 1119 1769 1118
4.	359 1739 2674 2673 1128 1766 1129 1130 1769 1118
5.	380 2052 322 44 18 2361 2362 1076 1408 1079 1772 1258 1119 1769 1118
6.	1331 1332 1789 1329 1445 1131 1773 1228 1306 1228 1258 1119 1769 1118
7.	1460 1094 1095 2050 1096 1097 1491 339 1492 2051 1100 1106 1107 1110 1115 1117
8.	1298 1283 1789 1329 1330 1329 1445 1131 1773 1228 1258 1119 1769 1118
9.	1481 2640 1338 1122 1784 1321 1767 1127 1120 1119 1769 1118
10.	186 132 1060 307 2052 322 44 1075 1114 2053 1113 2053 1112 1771 1111 1110 1115 1117
11.	1337 1336 1783 1781 1344 1342 1778 2672 1767 1127 1120 1119 1769 1118
12.	1327 1445 1775 1073 1070 2361 2362 1076 1770 1771 1111 1110 1115 1117

Hub No : 1463	
1.	823 828 821 2484 841 840 839 837 2479 838 963 838 2479 836 2482 833 834 2492 967 968 970 2498
2.	1515 873 713 2494 2495 874 875 2496 876 2496 880 969 971 2497 2498
3.	826 824 825 2499 820 2470 823 828 821 2484 2462 2430 2429 1049 1407 2479 836 2482 833 834 2492 967 968 970 2498
4.	887 2486 886 2488 888 878 2491 2492 834 833 832 833 834 2492 967 968 970 2498
5.	1000 999 998 997 1377 987 2505 973
6.	975 2507 2506 974 2505 973
7.	964 956 964 2481 2712 1531 2491 2492 967 968 970 2498
8.	822 830 829 831 2483 832 833 834 2492 2491 1531 2712 1456 966 1456 2712 1531 2491 2492 967 968 970 2498
9.	988 2511 2510 987 2505 973
10.	879 2514 875 2496 876 2669 877 878 2491 2492 967 968 970 2498
11.	885 2669 876 2496 880 969 971 2497 2498
12.	972 973
Hub No : 460	
1.	1363 1364 406 445 2244 448 2245 2206 1502 452
2.	548 545 2228 514 513 2237 512 511 510 509 1434 507 1440 486 2213 483 482 2214 2218 452
3.	405 2357 404 2356 446 448 449 450 1501 455 454 453 456 1502 452
4.	407 1364 406 445 2244 448 2245 431 1365 432 452
5.	527 510 509 1434 507 1440 486 506 2212 523 2211 524 2219 1502 452
6.	427 2350 422 2349 401 400 1439 399 436 435 2246 2220
7.	466 468 2267 470 463 470 2270 461 462 1526 2220
8.	464 2269 2268 2263 442 443 1471 440 439 440 437 2249 2248 435 2246 2220
9.	551 547 546 500 499 502 498 496 2275 2252 492 474 488 476 2223 2222 1526 2220
10.	1541 395 396 398 399 436 428 429 434 433 430
11.	441 2266 2265 469 2267 470 2270 461 462 1526 2220
12.	397 398 399 436 435 434 433 447 433 430
13.	1527 503 505 508 505 2663 484 483 482 2214 2218 452
14.	467 468 2267 470 2270 461 479 480 478 480 479 461 462 1526 2220
15.	516 2202 2208 2209 522 2211 504 2217 326 453 456 1502 452
16.	394 1471 440 437 2249 438 2249 2248 435 2246 2220
17.	459 2618 458 1501 451 2205 2206 1502 452
18.	403 2358 402 2358 2245 447 433 430 460
19.	495 494 471 472 473 479 461 462 1526 2220
20.	497 2252 2275 491 2226 487 489 2225 2222 1526 2220
21.	501 2663 484 483 2213 2215 525 2215 485 482 2214 2218 452
22.	490 2224 2223 1518 2223 2222 1526 2220
23.	477 476 481 476 2223 2222 1526 2220

24.	1525 2212 523 2211 524 2219 1502 452

Hub No. :1373

1.	779 892 2587 2590 2593 782 2593 2594 802 800 801 799 2606 798 2605
2.	780 782 2593 2594 803 2594 802 800 801 799 2606 798 2605
3.	788 790 789 790 791 792 2595 2604 793
4.	788 790 789 790 791 792 2595 2604 793
5.	797 2599 2600 2601 795 794
6.	1528 791 792 2595 2604 793
7.	796 2600 2601 795 794

Hub No :1367

1.	92 90 1606 89 167 1625 1622 168
2.	170 1619 171 1619 1620 167 1625 1622 168
3.	91 93 90 1606 89 167 1625 1622 168
4.	172 1630 1482 131 1482 1630 174 1631 175 1629 176 1621 169
5.	86 87 85 1618 2630 88 1625 1622 168
6.	173 1630 174 1631 175 1629 176 1621 177 1621 169
7.	187 1622 168
8.	178 177 1621 169

Hub No :1387

1.	1313 1312 1402 2680 1311 1310 2378 719 1388 2377
2.	902 2130 2131 905 2136 2377 907 1059 907 2377
3.	916 2157 917 918 919 2394 2395 920 921 922 923 924 898 2416 1462 901 1465 2392 903
4.	658 904 2130 2131 905 2136 915 1048 915 2136 2377
5.	813 2419 1031 1033 1032 1036 1032 1033 2418 1035 2416 901 1465 2392 903
6.	819 813 2419 845 844 2464 827 1041 1495 1039 1045 1044 1043 2417 1462 901 1465 2392 903
7.	1046 1538 1374 1537 1374 1045 1044 1043 2417 1462 901 1465 2392 903
8.	1056 1055 1052 1054 2423 1045 1044 1043 2417 1462 901 1465 2392 903
9.	736 2397 1057 2398 2394 909 908 910 1048 915 2136 2377
10.	1319 1320 2370 1324 2370 2369 1900 2373 1322 199 2375 906 2377
11.	1458 2464 844 845 2419 847 1029 2708 2388 1030 805 806 807 2391 809 2392 903
12.	815 811 847 1029 2708 2388 1028 1307 1025 719 1388 2377
13.	1026 2681 1304 1027 2389 1315 1028 1307 1025 719 1388 2377
14.	290 228 2371 227 2368 204 1322 199 2375 906 2377
15.	846 845 844 2464 827 1041 1040 1041 1495 1039 1045 1044 1043 2417 1462 901 1465 2392 903
16.	913 1038 912 2134 1047 911 909 908 910 1048 915 2136 2377
17.	1328 2370 2369 1900 2373 1311 1310 1309 1308 2713 1025 719 1388 2377
18.	1034 1036 1032 1033 2418 1035 2416 901 1465 808 1465 2392 90
19.	1042 2462 2430 1537 1374 1045 1044 1043 2417 1462 901 1465 2392 903
20.	1318 2382 2381 2713 1025 719 1388 2377

Hub No:604	
1.	630 2311 629 1517 606 1517 605
2.	613 2689 614 615 1516 2699 603
3.	612 2299 619 2299 611 610 618 609
4.	566 592 585 2286 600 2307 601 602 2699 603
5.	622 2302 2304 2698 608 607 605
6.	559 592 585 2286 600 2307 2705 2313 628 1517 60
7.	627 2311 629 1517 605
8.	586 2285 587 585 2278 599 598 2287 600 2286 2707 2699 603
9.	623 2305 624 606 1517 605
10.	616 2295 618 609
11.	621 2303 620 2303 618 609
Hub No :569	
1.	544 1503 1441 553 593 1454 595 590 557 591 2242 1510 563 1455
2.	599 2278 2277 2276 557 560 2241 561 567 568 1455
3.	503 546 547 2228 514 549 514 2228 545 548 2229 578 2255 579 589 2256 571 2258 2259
4.	619 2299 612 2691 2692 2689 614 615 2294 581 2289 2282 2260 2258 571 597 568 1455
5.	550 514 2228 547 546 500 546 547 2228 545 548 2229 578 2255 579 589 2256 571 2258 2259
6.	607 605 604 603 2699 1516 2284 580 2289 2282 2260 565 2280 562 2259
7.	551 547 2228 545 548 2229 578 2255 579 588 577 575 574 2260 564 1510 563 1455
8.	586 2279 566 592 559 2242 1510 570 1510 563 145
9.	621 2303 618 2295 613 2689 2291 583 1524 2288 2262 572 573 574 2260 2258 2259
10.	541 1441 553 593 1454 595 558 595 590 557 591 2242 1510 563 1455
11.	620 2303 618 2295 613 2689 2291 583 582 2262 572 573 574 2260 2258 2259
12.	611 610 618 2295 616 2295 613 2689 614 615 2294 581 2289 2282 2260 2258 2259
13.	587 585 592 559 2242 1510 563 1455
14.	555 2239 554 2238 558 595 590 557 591 2242 1510 563 145
15.	609 604 603 2699 1516 2284 580 2289 2282 2260 2258 2259
16.	576 577 575 574 2260 2258 2259
Hub No : 1470	
1.	376 1698 1699 1354 22 24 1706 25 1477 358 1727
2.	355 22 356 1697 378 1696 1695 144 143 1693 1692 1694
3.	39 1741 1737 31 1725 40 1725 1723 1724 1477 358 1727
4.	377 375 1678 1680 1681 1692 141 140 142 1694
5.	30 1739 359 1477 358 1727
6.	208 205 1731 1730 201 203 1158 1729 202 1728
7.	208 205 1731 1730 201 203 1158 1729 202 1728
8.	1155 1156 1157 1742 1735 200
9.	146 1707 1706 25 1477 358 1727
10.	139 1690 138 1691 1728 1470
11.	29 1724 1477 358 1727

Table A.5: Bus trips on the feeder routes connecting hubs.

S.No	Stop	Demand satisfied	Route length(m)	Bus Trips
Hub no: 1489				
1	680	11816	5249	196
2	364	11744	7359	195
3	722	2601	6611	43
4	721	11798	6219	196
5	1450	3258	6734	54
6	1375	11509	5966	191
7	230	1626	6549	30
8	306	1989	5229	33
9	645	11778	5949	196
10	458	1626	4089	30
11	1066	12010	7049	200
12	363	1626	4997	30
13	179	1693	5611	30
14	858	11732	6305	195
15	674	11816	6441	196
16	1062	1626	4939	30
17	1074	11778	5478	196
18	1410	11778	4682	196
19	1519	1626	4424	30
20	222	1626	4622	30
21	669	11816	4135	196
22	672	11778	3737	196
23	656	1626	3390	30
Hub No : 1442				
1	949	12782	12055	55
2	1053	11744	12337	30
3	1423	2601	13303	43
4	964	11798	13356	169
5	695	3258	14096	46
6	882	11509	13281	191

S.no	Stop	Demand satisfied	Route length(m)	Bus Trips
7	762	1634	12264	30
8	854	3001	12286	50
9	866	11778	10202	196
10	1538	1626	9956	30
11	755	12010	11398	200
12	896	1626	9712	30
13	703	1693	12087	30
14	883	11732	10823	30
15	863	12308	10702	62
16	951	1626	13324	30
17	961	11778	9676	34
18	648	12261	7280	30
19	769	1626	6579	30
Hub No : 1350				
1	272	12837	17766	213
2	9	11744	17333	195
3	236	3851	19267	64
4	392	11829	18385	197
5	283	3258	21345	54
6	180	12759	19558	212
7	45	1634	18463	30
8	16	5691	17740	94
9	1451	13162	16391	219
10	1371	2971	14789	49
11	216	13260	18602	221
12	313	2876	15116	30
13	72	1693	17509	30
14	70	11732	15466	77
15	304	13558	17260	184
16	237	2876	19349	47
17	1417	13028	15277	217
18	15	12261	11488	30
19	282	1626	11944	30
20	349	1626	10487	30

S.no	Stop	Demand satisfied	Route length(m)	Bus Trips
21	354	11816	7678	30
22	288	11796	8864	36
23	245	2876	6391	47
24	382	0	2626	30
Hub No : 1508				
1	36	13113	22731	218
2	1125	12345	24246	205
3	1335	4489	24211	74
4	359	12430	23315	97
5	380	3990	28093	66
6	1331	13360	24879	222
7	1460	1767	24351	30
8	1298	6292	23207	40
9	1481	13763	22988	92
10	186	3034	21526	50
11	1337	13861	25464	30
12	1327	2938	21590	48
13	1345	2294	23626	30
14	1105	11798	19423	55
15	1343	14159	22495	30
16	1104	2938	21943	48
17	1099	13090	18002	30
Hub No : 1469				
1	1282	13139	33333	218
2	1172	13270	31641	221
3	1233	5414	31177	30
4	1153	12557	30246	74
5	1217	4155	36785	32
6	1161	13487	33621	30
7	1167	1914	32757	31
8	1241	7217	29753	30
9	1242	14688	32188	54
10	1230	3161	27710	30

S.no	Stop	Demand satisfied	Route length(m)	Bus Trips
11	1162	13988	31474	30
12	1229	3863	27382	30
13	1261	2294	29546	38
14	1163	11925	24574	30
15	1221	14286	27157	30
16	1164	3065	26595	30
Hub No : 1463				
1	823	13139	40415	218
2	1515	13270	36994	221
3	826	5414	43692	90
4	887	12557	36825	107
5	1000	6512	41490	108
6	975	15844	37961	64
7	964	1914	36540	31
8	822	7217	38026	120
9	988	17045	36161	30
10	879	3161	32479	52
11	885	13988	35172	30
12	972	6220	30402	30
Hub No : 460				
1	1363	15429	46904	257
2	548	15453	43617	257
3	405	7626	50555	127
4	407	14680	41748	244
5	527	8695	46905	144
6	427	16133	45256	268
7	466	2116	41629	35
8	464	7217	44082	120
9	551	17045	43098	284
10	1541	4154	37265	69
11	441	13988	40361	208
12	397	7213	35650	120
13	1527	4595	34813	76

S.no	Stop	Demand satisfied	Route length(m)	Bus Trips
14	467	11925	30373	198
15	516	16409	31731	115
16	394	3065	31468	51
17	459	15213	22952	253
18	403	13116	16597	214
19	495	1626	16466	30
20	497	1626	14476	30
21	501	13939	12024	30
22	490	11796	12538	30
23	477	2876	9726	30
24	1525	2123	5164	30
Hub No : 1373				
1	779	15429	53566	30
2	780	15453	50153	71
3	788	20573	54600	342
4	797	15910	44726	76
5	1528	21642	49785	33
6	796	17363	47856	30
Hub No : 1367				
1	92	20959	60865	30
2	170	20947	59862	83
3	91	26085	61864	44
4	172	16644	53683	263
5	86	27136	56226	30
6	173	18097	54108	51
7	187	7610	44309	30
8	178	7951	46245	30
Hub No : 1387				
1	1313	20959	65662	349
2	902	20947	65929	30
3	916	27177	68927	452
4	658	16644	60720	30
5	813	28228	60873	120
6	819	19330	60999	30
7	1046	9118	50039	151

S.no	Stop	Demand satisfied	Route length(m)	Bus Trips
8	1056	9043	51304	150
9	736	17045	49781	79
10	1319	4154	43766	68
11	1458	15080	45765	169
12	815	7213	40746	83
13	1026	4595	39615	76
14	290	11925	35454	60
15	846	17924	38394	116
16	913	3065	36845	51
17	1328	15 213	28616	253
18	1034	14208	21610	236
19	1042	2926	21692	41
20	1318	1626	17651	30
Hub No : 604				
1	630	21937	69673	180
2	613	22603	69553	133
3	612	28737	73352	49
4	566	18300	67190	184
5	622	28823	64868	64
6	559	20001	70149	103
7	627	10096	53362	39
8	586	10699	62283	43
9	623	17716	54305	32
10	616	5714	47547	34
11	621	16640	49494	30
Hub No : 569				
1	544	25095	75547	418
2	599	25672	74307	200
3	503	28737	79380	129
4	619	21369	74503	169
5	550	28823	70833	251
6	607	20001	77889	166
7	551	13190	60155	219
8	586	13793	68043	229
9	621	17716	60049	32

S.no	Stop	Demand satisfied	Route length(m)	Bus Trips
10	541	8808	53576	146
11	620	16640	55283	46
12	611	7213	47695	30
13	587	7689	44063	30
14	555	15019	40899	30
15	609	17924	46726	35
16	576	3065		30
Hub No : 1470				
1	376	25165	82253	294
2	355	25672	79069	264
3	39	28737	85627	413
4	377	21369	79751	356
5	30	28823	75295	480
6	208	20001	82080	122
7	357	13190	65284	172
8	1155	14288	71896	85
9	146	17786	64464	30
10	139	8808	56684	42
11	29	16640	58386	49
Hub No : 96				
1	167	25201	93104	103
2	331	34901	89897	90
3	162	37930	96112	123
4	159	30562	86203	34
5	1448	38016	79663	33
6	104	20001	86007	30
7	106	13190	69158	30
8	166	23481	75078	30
Hub No : 1428				
1	978	29080	115172	97
2	1023	38438	105423	30
3	1303	40642	112101	30
4	1247	33797	104959	167
5	1251	40909	95721	63